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DIAGNOSIS AND OPERATIVE TREATMENT

OF

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OF THE

STOMACH AND INTESTINES.

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# Diagnosis and Operative Treatment of Gunshot Wounds of the Stomach and Intestines.

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## DIAGNOSIS AND OPERATIVE TREAT- MENT OF GUNSHOT WOUNDS OF THE STOMACH AND INTESTINES.

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The existence of a visceral lesion of the stomach or intestines must be suspected in every case where a bullet penetrates the abdominal cavity; hence the first step in the diagnosis of gunshot injuries of these organs must be directed towards establishing the fact that penetration has occurred.

### DIFFERENTIAL DIAGNOSIS BETWEEN NON PEN- ETRATING AND PENETRATING GUNSHOT WOUNDS OF THE ABDOMEN.

This part of the diagnosis may be easy or difficult, according to circumstances. If the bullet has passed through the body, and the wounds of entrance and exit occupy such positions that a direct line connecting them will necessarily pass through the abdominal cavity, there can be but little doubt that both abdominal walls have been perforated at opposite points, and that the bullet has traversed that part of the peritoneal cavity interposed between them. In obese persons, the exact outlines of the peritoneal cavity cannot be located with absolute accuracy, and on this account some doubt may remain, in case two bullet wounds, made by a single bullet, are found over the anterior or lateral aspect of the pendulous abdomen, whether the peritoneal cavity between the wounds of entrance and exit falls in the track made by the bullet.

In a case of this kind that recently came under my observation, I decided this important question by injecting hydrogen gas into the wound of en-



trance. A glass tube corresponding to the size of the bullet was connected with the rubber tube of a rubber balloon in which the gas was stored, and was inserted into the wound of entrance; by gently compressing the balloon the gas was forced along the track made by the bullet until it escaped at the wound of exit, which demonstrated that the wounds communicated with each other, and consequently must have been made by the same bullet. In order to show conclusively that the peritoneal cavity had not been opened at any point along the track made by the bullet, the wound of exit was closed by compression, made with self-locking hæmostatic forceps, and insufflation was resumed. After the wound had become fully distended, the resistance to the escape of gas was suddenly increased, which would not have been the case had the peritoneal cavity been opened, as in that case the gas would have escaped into the peritoneal cavity, making a free tympanites which could have been easily recognized by the usual physical symptoms. Instead of this condition, however, a circumscribed area of emphysema was caused by a continuation of the insufflation, which, with the absence of a free tympanites and the escape of gas at the wound of exit, I regarded as a positive evidence that penetration had not occurred. The wounds were not drained, but were treated and dressed in accordance with strict antiseptic precautions, and healed by first intention.

The use of the probe in such cases is of no value whatever in determining the existence or absence of penetration, and a reliance upon it as a diagnostic measure may lead to serious errors, both in diagnosis and treatment. Air should never be used for insufflating a bullet track for diagnostic purposes, as the air injected might become the direct means of infection. Hydrogen gas is a non-toxic, aseptic substance with valuable inhibitory antiseptic properties; qualities which

render it the most desirable substance to be used for inflating tubular wounds for diagnostic purposes.

Wounds through the body made with a bullet, in parts of the abdomen where, from the direction of the track, it is not certain whether or not the peritoneal cavity has been opened, call for a most careful examination to determine this point. If this cannot be done satisfactorily with the hydrogen gas test, the course of the bullet must be followed by a careful dissection from the wound nearest the point where we have reason to suspect a tear or perforation of the parietal peritoneum. If only one wound, the wound of entrance, is present, the question of penetration depends upon the shape and size of the bullet, the distance from which and direction in which the shot was fired, the amount and nature of the clothing covering the point of impact, the position of the patient at the time he received the injury, and the anatomical character of the parts interposed between the wound of entrance and the abdominal cavity.

1. *Shape and Size of the Bullet.*—Other things being equal, the larger the bullet the greater the probability of deep penetration, as in the present construction of firearms the amount of powder in the cartridge is proportionate to the weight of the bullet. A conical bullet penetrates more deeply than a round bullet of equal weight. At close range, bullets fired from firearms of the smallest calibre possess sufficient force to penetrate the soft tissues of the thickest abdominal wall. In my experiments on dogs with different sized shot, I used a double-barreled shotgun, No. 12 gauge; the cartridges were charged with the usual amount of powder used for duck hunting, and contained from four to twelve shots. The dogs were etherized, strapped on a Pasteur table and placed in an erect position, and the shooting was done at a distance of twenty feet. The largest shot, calibre 18, often passed through the body, if no bone came

in its way, while even No. 8 shot invariably penetrated the anterior abdominal wall.

2. *Distance and Direction of the Bullet.*—In reference to the distance at which the shot is fired, the result will be largely influenced by the size and shape of the bullet and the quantity of powder used in the charge. A 38- or 45-calibre conical bullet propelled by the explosion of sixty to seventy grains of powder, fired at a distance of two hundred paces, will not only penetrate the abdominal cavity, but will pass through the body if its course is not impeded by the ribs, spinal column, or pelvic bones; while a round bullet of 22-calibre may fail to pass through the fleshy part of the abdominal wall at a distance of ten to twenty paces. In my experiments on the cadaver I used a 22-calibre Stephenson rifle and conical bullets. The cadaver was placed in the erect position, and the bullet was fired at a distance of twenty feet, directly in front of the subject. In every instance the bullet perforated the anterior abdominal wall, passed across the peritoneal cavity, and was found lodged at variable depths in the posterior abdominal wall.

The direction of the bullet plays an important part in the differential diagnosis between penetrating and non-penetrating wounds of the abdomen. A bullet fired in a direction which corresponds with the shortest and most direct route from the surface into the peritoneal cavity is most likely to cause a penetrating wound. Thus, bullets will enter the abdominal cavity with a minimum degree of force if in their course they pass through the thinnest portion of the abdominal wall, which corresponds with the linea alba and, notably, the umbilicus. A bullet taking a less direct route, especially if of small calibre or if fired at great distance, may become arrested in its course after passing through from two to six inches or more of soft tissues before it reaches the abdominal cavity. A bullet may reach the ab-



dominal cavity even if the external wound be located a considerable distance from this cavity. In one of my cases, a suicide, the bullet entered the cavity of the chest on the left side, passed through the lower lobe of the left lung, and entered the abdominal cavity through the diaphragm, where it perforated the stomach from above downwards. Perforation of the intestines may also take place in the lowest part of the abdominal cavity by the passage of a bullet through the pelvic structures, the external wound being remote from the perforation in the parietal peritoneum and the visceral lesions.

3. *Amount and Nature of Clothing at Point of Impact of Bullet.*—Many lives have been saved by thick, firm clothing breaking the force of the bullet, which then causes an ordinary, innocent flesh-wound instead of a penetrating wound, which would have been caused had the surface been less efficiently protected. In other cases the injury was modified by the bullet impinging against a button, belt, buckle, note- or pocket-book, which not only diminished the force of the missile, but changed its course from a direct route into the abdominal cavity into an oblique direction through its wall. The suicide who wants to make sure of the deadly intent upon his own life should divest himself of the clothing covering the heart, so as to remove any obstacles which might deviate or diminish the force of the bullet.

4. *Position of Patient.*—In every case of gunshot wound of the abdomen it is important to ascertain as nearly as possible the exact position of the patient at the instant the shot was fired, as information thus obtained will be of great value in determining beforehand the probable course of the bullet. It is on account of the change of the relative position of the parts after the infliction of the wound that the track made by the bullet cannot usually be followed with a probe, as by the change in the position of the muscles, and by

the sliding of fascia and skin, obstructions are formed in different parts of the tubular wound. Remembering the exact position of the patient and his assailant, and imagining the direction of the bullet, its course through the tissues can be ascertained with at least an approximate degree of accuracy.

5. *Anatomical Character of Parts Interposed Between the Wound of Entrance and Abdominal Cavity.*—A conical bullet of large calibre, fired in close proximity to the body, will penetrate the tissues irrespective of their anatomical character and without deflection. Deflection of small bullets, and of large bullets fired at a considerable distance, is occasionally caused when they strike a smooth bony surface at an oblique angle, an occurrence which abruptly deviates the course of the missile. McGraw, of Detroit, has shown experimentally that deflection of bullets does not take place as often as had been formerly supposed. We have no reason to believe that the soft tissues of the abdominal wall, under any circumstances, offer sufficient resistance to change the course of a bullet. A partially spent bullet striking obliquely against the convex surface of the ribs, or against the spinous or lateral processes of the vertebræ, or the pelvic bones, may deflect a bullet in its course, and what appears upon first sight a penetrating wound may be simply a wound of the abdominal wall, with the bullet lodged in the tissues at a considerable angle from the line of entry. Deflection should therefore be thought of as a possible occurrence only when the bullet has entered the body and has met with a bony resistance in its course towards the peritoneal cavity.

#### *Exploration of Parietal Wound.*

Examination of gunshot wounds of the abdominal wall must be made with special reference to a positive differential diagnosis between penetrating and non-penetrating wounds. The diag-

nostic aids which I have just enumerated should be applied in every case before any attempt is made to demonstrate the depth and course of the wound by digital or instrumental exploration. A positive diagnosis must, however, be withheld until the exact course of the bullet has been revealed by a careful exploration of the wound-canal from the point of entrance of the bullet to the peritoneal cavity, if the bullet has penetrated, or sufficiently far to prove that the abdominal cavity has not been invaded.

Certain precautions should never be neglected during the first examination of gunshot wounds of the abdomen. In the first place, undue haste must be scrupulously avoided. A wound of the abdominal wall should never be touched without first procuring for the wound of entrance and for the surface a considerable distance beyond it, a perfectly aseptic condition by thorough disinfection. The parts should be scrubbed with warm water and potash soap, and then washed with a 1-1000 solution of corrosive sublimate, or a 5 per cent. solution of carbolic acid. The surgeon's and assistants' hands should be rendered aseptic in the same manner, special care being taken to disinfect the spaces underneath the finger-nails. Digital or instrumental exploration of gunshot wounds of the abdomen without the necessary antiseptic precautions must be regarded, in the light of modern surgery, as nothing less than criminal negligence, and such recklessness may become the direct cause of a fatal wound complication in case of injuries which, if treated upon strict antiseptic principles, would have resulted in recovery. The instruments used in exploring the wound must be rendered aseptic by boiling them for at least five minutes, or by passing them through the flame of an alcohol lamp.

If a large bullet has penetrated the abdominal cavity by the shortest possible route through a thin portion of the abdominal wall, the fact that



penetration has taken place often becomes evident by prolapse of the omentum into the wound-canal. In such a case, the surgeon verifies the diagnosis by seizing the visible portion of the omentum with a pair of dissecting or hæmostatic forceps, and by making traction, pulls the omentum further into the wound for identification. The appearance of the structure, as well as the course of the blood-vessels, will enable him to decide whether the prolapsed tissue is a part of the omentum, or a piece of fat from the subperitoneal fat or the panniculus adiposus. If the part under examination proves to be the omentum, the existence of penetration has been conclusively demonstrated, and the proper treatment for penetrating wounds is at once to be carried into effect.

The cases where such a rapid differential diagnosis between non-penetrating and penetrating gunshot wounds of the abdomen can be made, are comparatively few. In the majority of cases, exploration of the wound by a careful dissection furnishes the only positive and reliable means in determining that the bullet has entered the peritoneal cavity.

Digital exploration of the wound should never be relied upon in ascertaining the depth and course of the wound, as this procedure is not infallible in making a correct diagnosis, and as, in case the bullet has penetrated the abdominal cavity, the finger may push before it and into the peritoneal cavity infected foreign substances.

The use of the probe should be discarded in the examination of gunshot wounds of the abdomen for diagnostic purposes. The wound-canal is often so tortuous from displacement of the tissues forming its walls that it cannot be followed with a probe without fear of making false passages, an occurrence which could not fail to lead to erroneous conclusions in reference to the extent and course of the wound, and in regard to the pres-



ence of visceral complications which might demand prompt operative treatment.

In every case of gunshot wound of the abdomen, the track made by the bullet must be followed by enlarging the wound by an incision at least two inches in length, which should intersect the perforation where its diameter is greatest, and in the direction of the principal muscle involved by the perforation. Before this is done all the preparations for a laparotomy should have been completed, everything required in the treatment of visceral wounds should be on hand, and the consent of the patient and his friends obtained to proceed and do what may become necessary in case it is found that the bullet has entered the abdominal cavity and has caused visceral injuries which demand surgical interference.

It is often not an easy task to follow the track of a bullet with the scalpel through a thick abdominal wall. The best method of procedure is to insert a grooved director as far as it will pass without resistance, and then divide the tissues layer after layer, catching bleeding vessels with hæmostatic forceps as fast as they are cut, in order to keep the field of operation as nearly as possible in a bloodless condition. The bullet frequently discolours the tissues, and these discolorations are often important landmarks in following the wound. The divided tissues are held out of the way with sharp-toothed retractors, in order to enable the operator to follow the course of the bullet with his eye as well as with his instruments. When the point of the director is reached it becomes necessary to make a close inspection, and under no conditions should the knife be used until the wound-canal can again be identified and followed with the eye or the director. The dissection is to be made carefully and slowly until the opening in the parietal peritoneum is reached, which completes the first part of the diagnosis. In non-penetrating wounds the dissection is car-

ried down to the bullet, which is then removed. In case this is not practicable on account of the location of the wound, the nature of the parts involved, or the length of the track, it is extended sufficiently far to satisfy the operator that the abdominal cavity is intact. The operation is completed by adopting the usual treatment for non-penetrating wounds. By following the methods above described in differentiating between a non penetrating and penetrating gunshot wound of the abdomen, the surgeon is able to make a positive anatomical diagnosis, and in either case to adopt and carry into effect a rational plan of treatment.

*1. Diagnosis of Visceral Wounds of the Stomach and Intestines.*

Quite recently the assertion has been made by several good surgeons that laparotomy is a justifiable procedure in every case of penetrating gunshot wound of the abdomen, and the claim is made at the same time that a bullet which enters the peritoneal cavity must almost of necessity inflict visceral injuries which require direct surgical treatment. The statement must, however, be accepted as true, that in the absence of serious visceral lesions, penetrating gunshot wounds of the abdomen are injuries from which the patients are very likely to recover without operative treatment, and that when such patients are subjected to laparotomy, death may occur in consequence of the operation, and not as a result of the injury. An injury of this kind is a subcutaneous lesion which usually heals without any inflammation or suppuration, provided the bullet has not carried with it into the abdominal cavity foreign infected substances. I am firmly convinced that in most cases of spontaneous recovery after penetrating gunshot wounds of the abdomen, the favorable termination was due to the fact that the bullet did not produce any visceral lesions of the gastro-intestinal canal. In two of the six cases of gunshot

wound of the abdomen which have come under my observation during the last three years—and which will be reported further on—the absence of perforating wounds of the stomach and intestines was demonstrated by the hydrogen gas test, and both of these recovered. This appears like a large percentage, but my own experience so far has been in direct contrast with the assertions of a number of surgeons that all penetrating wounds of the abdomen require treatment by laparotomy.

*Experiments on the Cadaver.*

In order to throw more light on this important subject, I made a number of experiments on the cadaver to determine the frequency and number of visceral wounds of the stomach and intestines that may be expected in cases of penetrating gunshot wounds of the abdomen when the course of the bullet can be determined beforehand. These experiments I will relate very briefly.

The cadaver was suspended and placed in the erect position against a wall. The shooting was done at a distance of ten feet with a Stephenson rifle, carrying a 22-calibre conical bullet. The rifle was held on a level with the wound of entrance, so as to give to the bullet as nearly as possible an exact antero-posterior direction; that is, it was intended that the wound in the anterior abdominal wall should be on the same level as the wound in the posterior wall. As the experiments were made from one to three days after death, the abdomen was in every case somewhat distended by accumulation of gas in the intestines.

*Experiment 1.*—Male, fifty-four years, dead twenty-four hours, emaciated, rigor mortis well marked. Bullet entered through the linea alba, 1.8 cm. below the umbilicus. The abdomen was opened at once, and it was ascertained that the bullet had passed between the transverse colon and small intestine without causing any visceral injury, and had lodged in the posterior abdominal wall.

*Experiment 2.*—Male, forty-five years, dead thirty-six hours, very little emaciation. Wound of entrance 4 mm. to the right of the median line and 8.5 cm. below the umbilicus, producing in its course through the abdominal cavity one perforation on convex border of loop of small intestine, one perforation of the sigmoid flexure, and a wound in the upper portion of the bladder, which was found adherent to a loop of the ileum.

*Experiment 3.*—Male, thirty years, dead thirty hours, fairly well nourished. Entrance of bullet 4.5 cm. to the left of linea alba and 2 cm. below the umbilicus. Result: four perforations of the small intestine at mesenteric border, one on convex side, and one through the centre of adjoining loop.

*Experiment 4.*—Male, sixty years, dead eighteen hours, advanced marasmus. Bullet entered 7 cm. to the left of middle line and 1.5 cm. below the level of the umbilicus, causing three perforations in adjoining loops of intestine.

*Experiment 5.*—Male, forty-six years, dead twenty-four hours, greatly emaciated. Wound of entrance 5 mm. to the left of the median line and 1 cm. above the umbilicus, producing a double perforation of the transverse colon.

*Experiment 6.*—Male, thirty-five years, dead eight hours, well nourished, considerable tympanites. Ball entered 7.5 cm. to the right of the middle line and 15 mm. above the umbilicus, making in its course through the peritoneal cavity a marginal wound of the transverse colon.

*Experiment 7.*—Male, fifty-six years, dead eighteen hours, pronounced emaciation. Entrance of bullet 6 cm. to the left of linea alba, and 3 cm. above the level of the umbilicus. No visceral injuries could be found on most careful inspection of the abdominal cavity, the bullet having passed between the transverse colon and the small intestine.

*Experiment 8.*—Male, forty years, dead twen-



ty-four hours, moderate emaciation. Wound of entrance 1.2 cm. to the right of median line, and 2.5 cm. below the umbilicus. Examination of the abdominal cavity showed absence of any visceral injuries that would require surgical treatment, the bullet having passed through a triangular space formed by two adjoining loops of small intestine and the transverse colon.

*Experiment 9.*—Male, thirty-seven years, dead thirty-seven hours; no emaciation. Bullet entered 9 mm. to the right of the median line and 2.5 cm. above the umbilicus. Liver much enlarged, and stomach dilated so that the great curvature extended below the level of the umbilicus. In searching for visceral injuries it was found that the bullet had passed through the margin of the liver close to the suspensory ligament, above the lesser curvature of the stomach, perforating at the same time the head of the pancreas.

*Experiment 10.*—Male, twenty-five years, dead thirty-six hours, well nourished. Wound of entrance 3.9 cm. to the left of the middle line and 9 mm. above the level of the umbilicus. The internal injuries produced consisted of one marginal wound and three double perforations of the small intestine, with two wounds of the mesentery.

*Experiment 11.*—Male, forty-nine years, dead thirty-two hours, moderate emaciation. Bullet entered 3 cm. to the left of the median line and 3.3 cm. above the umbilicus, passing in its course through both walls of the cardiac extremity of the stomach near the great curvature.

*Experiment 12.*—Male, sixty-two years, dead seventy-two hours, considerable obesity. Wound of entrance 7.5 cm. to the right of the median line and 3.1 cm. above the umbilicus, causing a wound of the right lobe of the liver and passing through the lower segment of the right kidney.

*Experiment 13.*—Male, forty-one years, dead twenty-three hours, extreme emaciation. Ball entered 9 mm. to the right of the median line and

3.6 cm. above the level of the umbilicus. The only internal injury found was a small wound at the very margin of the left lobe of the liver, the bullet having passed between the pyloric extremity of the stomach and the transverse colon.

*Experiment 14.*—Male, thirty-six years, dead twenty-eight hours, moderate emaciation. Wound of entrance 4.2 cm. to the right of the median line, and 3 mm. above the umbilicus, passing through the transverse colon.

The result of these experiments confirmed me in the opinion that I have entertained for years, that a bullet passing through the abdominal cavity does not produce visceral injuries as constantly as we have been taught to believe. It will be seen from the experiments that in four instances, experiments 1, 7, 8, and 9, the bullet passed through the abdominal cavity in an antero-posterior direction without causing any visceral injury which would require surgical interference. In experiment 13, the bullet grazed the margin of the liver, producing an insignificant wound which could not have given rise to more than trifling hæmorrhage, and which would have healed promptly without any direct treatment. In the remaining experiments where no visceral lesions were produced, the only possible indications for laparotomy would have arisen on account of hæmorrhage; but as a careful examination did not reveal the existence of injury of any vessel of sufficient size to give rise to this indication, it is only fair to assume that patients would recover from such injuries without any special surgical treatment.

If in two out of six cases, and in four out of fourteen experiments, a bullet can traverse the abdominal cavity through from wall to wall without inflicting a mortal visceral injury, it appears certainly of the greatest importance, from a practical standpoint, to draw a line of distinction in the treatment of penetrating gunshot wounds of

the abdomen with and without visceral lesions. Laparotomy should not be performed simply because a bullet has entered the abdominal cavity, but its performance should be limited to the treatment of intra-abdominal lesions which, without operative interference, would tend to destroy life.

*Course of Bullet.*

My clinical experience and experimental work have satisfied me that the course of the bullet determines not only the existence, but also the number of visceral wounds of the gastro-intestinal canal. It may be laid down as a rule, that the shorter the route of the bullet through the abdominal cavity, the greater the possibility that the intestines will escape injury, and the fewer the number of perforations. A bullet passing through the peritoneal cavity in an antero-posterior direction will meet with fewer intestinal loops than one that is fired through the abdomen obliquely or from side to side. The experiments related have demonstrated conclusively that bullets passing through the abdomen at points above the umbilicus are most likely to miss the intestines and to inflict simple penetrating wounds. On the other hand, bullet wounds in the upper segment of the abdomen most frequently inflict visceral injuries which require treatment by laparotomy for the arrest of dangerous hæmorrhage, as a wound of the liver, kidneys, or spleen gives rise to alarming and often fatal hæmorrhage. My experiments on dogs have taught me that the largest number of perforations are produced by bullets which pass from side to side, or obliquely through the abdomen at a point below the level of the umbilicus. A bullet passing through the abdominal cavity in an antero-posterior direction seldom causes more than four perforations, while fourteen and sixteen perforations are often found if it has passed transversely or obliquely through the abdomen at a point below the umbilicus.

The practical deductions to be drawn from the above remarks are that, if in any given case it can be shown from reliable information that a bullet has crossed the abdominal cavity in an antero-posterior direction at or above the umbilical level, the gastro-intestinal canal may have escaped injury, while if it is probable that the bullet has passed through the abdomen from side to side or obliquely at a point below the umbilicus, it is not only almost certain that it has injured the intestines, but it is almost equally certain that it has produced from three to sixteen perforations.

### *General Symptoms.*

The general symptoms in cases of gunshot wounds of the abdomen, with the exception of those due to profuse internal hæmorrhage, furnish absolutely no reliable information in the differentiation between simple penetrating wounds and penetrating wounds complicated by visceral injuries.

Severe shock may attend even a non-penetrating wound, and it may be entirely absent in cases of multiple perforations. In one of my cases where I found twelve perforations, the patient walked a considerable distance immediately after he was shot, and was then transported on a wagon six miles to the hospital, and on his arrival he did not present a single symptom of shock or any other evidence of serious internal injuries.

Vomiting takes place as frequently in wounds of the abdominal wall and simple penetrating wounds as when the viscera have been injured.

Pallor is present in all gunshot wounds of the abdomen soon after the receipt of the injury, and it is only more pronounced when produced, at least in part, by sudden and severe internal hæmorrhage.

Pain is a very unreliable symptom, as it may be moderate or almost completely absent soon



after the injury has been inflicted, even when subsequently multiple perforations are found.

The pulse at first is slow and compressible in all cases of gunshot wounds of the abdomen, and nothing characteristic in its qualities is observed even if the stomach or intestines have been injured.

Hæmorrhage caused by wounds of any of the large vessels, mesentery, or any of the vascular organs, as the spleen, liver or kidneys, gives rise to progressive anæmia, small, rapid pulse, cold, clammy perspiration, dilated pupils, yawning, vomiting, and, in extreme cases, syncope and convulsions.

#### *Local Symptoms.*

The local symptoms are of no more value in determining the existence of visceral injuries in penetrating gunshot wounds of the abdomen than are the general symptoms just enumerated.

1. *Hæmorrhage*. — External hæmorrhage is slight or entirely wanting, unless an artery or vein in the abdominal wall has been injured. The bleeding from visceral wounds gives rise to accumulation of blood in the peritoneal cavity; this can be recognized by physical signs which denote the presence of fluid in the free abdominal cavity and by the general symptoms indicating progressive anæmia; increasing pallor of the face and visible mucous membranes, small, feeble pulse and dilated pupils. Gunshot wounds of the stomach are often followed by hæmorrhage into this organ and hæmatemesis. Hæmorrhage into the bowels from wounds of the intestines is seldom followed by bloody stools sufficiently early to be of any diagnostic value.

2. *Emphysema*. — Circumscribed emphysema in the tissues around the track of the bullet has been regarded as an important sign of the existence of intestinal perforation. This symptom is misleading and absolutely devoid of diagnostic value, as I have seen quite extensive emphysema of the subcutaneous tissues along the track of a

bullet-wound of the abdominal wall where I was able to determine positively that the bullet did not penetrate the peritoneal cavity. It is very seldom present as the result of escape of gas when the stomach or intestines have been perforated.

3. *Free Tympanites*.—The accumulation of any considerable quantity of gas in the peritoneal cavity can be easily recognized by the disappearance of the normal liver dulness caused by the presence of gas between the surface of the liver and the chest-wall. This condition has been sought for in cases of perforating wounds of the abdomen and has been laid down as one of the symptoms which point to the existence of visceral wounds of the gastro-intestinal canal.

In the normal condition the quantity of gas contained in the intestines is so small that even if all of it should escape into the peritoneal cavity its presence in this locality could not be recognized by physical signs. If we remember that only a small portion of the gaseous contents of the intestinal canal will escape even if a number of perforations exist, it is evident that this symptom should not even be taken into consideration in making a diagnosis. In more than a hundred experiments on dogs I never found enough gas in the peritoneal cavity, after penetrating gunshot wounds of the abdomen, to be recognized by physical signs, and I am confident that the same holds true in gunshot wounds of the abdominal cavity in man.

4. *Escape of Fæces*.—Escape of fæces through the bullet-wound is of exceedingly rare occurrence, and is only possible when the wound has been made with a large bullet and when the visceral wound is directly opposite the internal opening in the abdominal wall. It is met with more frequently in wounds of the large than of the small intestine. When this symptom is present, it is conclusive proof of the existence of

a visceral wound of the intestines and the character of the intestinal contents will furnish some indication as to what part of the bowel has been injured.

With the exception of the last mentioned symptom, there is nothing about the local or general symptoms in cases of perforating gunshot wounds of the abdomen that would enable the surgeon to decide with any degree of positiveness whether the bullet had produced any visceral injuries of the gastro-intestinal canal, and, consequently, whether laparotomy should or should not be performed.

I think every modern surgeon will agree with me in the assertion that a perforation of any portion of the gastro-intestinal canal large enough to permit the escape of the contents of the stomach or intestines into the peritoneal cavity must be considered for all practical and medico-legal purposes a mortal injury, and that its discovery furnishes a positive indication for laparotomy. In exceptional cases, where all the conditions are favorable for such a termination, a spontaneous recovery may take place by the wounded intestine or stomach forming speedy adhesions with serious surfaces, thus protecting the peritoneal cavity against infection. One of the most important conditions for such a favorable termination to take place is that the wounded organ should be empty at the time the injury is inflicted and until the peritoneal cavity has been shut off by adhesions. These cases, however, are the exception; extravasation, septic peritonitis, and death are the rule.

If a simple penetrating wound of the abdomen is an injury from which a large majority of patients recover without exposing them to the additional risks of a laparotomy, and since bullet-wounds of the gastro-intestinal canal are attended by such an enormous mortality without operative interference, the practical value and

importance of a correct diagnosis before deciding upon a definite plan of treatment becomes apparent. Hence the necessity of resorting to the use of the

*Hydrogen Gas Test in the Diagnosis of Perforating Gunshot Wounds of the Abdomen.*

It is apparent that if some infallible diagnostic test could be applied in cases of penetrating gunshot wounds of the abdomen, which would indicate to the surgeon the presence or absence of visceral lesions of the gastro-intestinal canal, the indications for aggressive and conservative treatment would become clear.

As we can never expect by a study of clinical symptoms, or by the ordinary physical examination to fill this gap, I was induced three years ago to search for some reliable test which in such cases should prove that the penetrating bullet had injured some portion of the gastro-intestinal canal. It occurred to me that a wound in the stomach or intestine should be sought for in some such way as the plumber locates a leak in a gas-pipe. The first object to be accomplished was to prove the permeability of the entire gastro-intestinal canal to inflation of air; and the next step was to find some innocuous gas which when inflated would escape from the intestinal wound into the peritoneal cavity, and from there through the external wound, where its presence could be demonstrated by some infallible test.

*Permeability of the Ileo-Cæcal Valve to Rectal Insufflation of Air or Gas.*

A great deal has been said and written in reference to the permeability of the ileo-cæcal valve to injections of fluids into the rectum, or to the insufflation of air or gases. The majority of those who have studied this subject clinically or experimentally make the positive assertion that the ileo-cæcal valve is perfectly competent and effectually guards the ileum against the entrance of both



fluids and gases forced into the rectum; while others insist that it is permeable only in exceptional cases, and only a few admit that its resistance can be overcome by a moderate and safe degree of pressure. I made a number of experiments on dogs to test the resistance of the ileo-cæcal valve to rectal injections of fluids, and found that the force requisite to overcome it was so great that in every experiment where I succeeded in injecting fluid into the ileum, I found multiple longitudinal lacerations of the peritoneal surfaces of the cæcum and colon. The experiments with insufflation of air and hydrogen gas proved uniformly successful, not only in causing incompetency of the ileo-cæcal valve under a pressure which never resulted in injury to any of the intestinal tunics, but in every instance I could force the air or gas from anus to mouth. Of the many experiments which I made, I will relate only one in illustration of the manner in which the experiments were made, and the results.<sup>1</sup>

*Experiment.*—"Dog, weight thirteen pounds. Animal profoundly etherized, and air forced into the rectum through short rectal tube connected by rubber tubing with inflated rubber balloon. The distended colon could be clearly mapped out by percussion before a gurgling sound in the region of the ileo cæcal valve indicated that the air had entered the ileum. As soon as the air commenced to distend the ileum the middle of the abdomen became prominent and tympanitic. It was found that as soon as the ileo-cæcal valve had been rendered incompetent by the gradual elastic dilatation of the cæcum, less force was required in distending the remaining portion of the gastro-intestinal canal. The inflation was carried to the extent of distending the stomach, an event which was easily recognized by a considerable prominence in the epigastric region which was

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<sup>1</sup> Journal of the American Medical Association, June 23-30, 1888.

tympanitic on percussion. At this time an elastic tube was inserted into the stomach, and its free end immersed under water. Bubbles of air escaped freely, and the abdominal distension was materially diminished. As the inflation was continued the air escaped through the stomach tube, showing that a moving current of air existed between the rectal and stomach tube."

The same experiment was made on the human subject with similar results, showing that in the human being the ileo-cæcal valve can be rendered incompetent by rectal insufflation of air or gas with the same ease as in the lower animals. These experiments demonstrate conclusively that in the human subject by a moderate degree of force, short of producing any injury of the tunics of the intestines, air can be forced along the entire alimentary tract, and that this procedure can be employed with perfect safety for diagnostic and therapeutic purposes in all cases where the tissues of the intestinal wall have not suffered too much loss of resistance from antecedent pathological changes.

Accurate experiments to determine the force required to render the ileo-cæcal valve incompetent by insufflation of air or gas had so far not been made, and as it was exceedingly important to obtain some accurate information on this subject, a number of experiments were made on dogs and on the human subject. In all experiments air or hydrogen gas was used. The inflation was made with a rubber balloon. The pressure was estimated either with a mercury gauge, or with a manometer, such as is used by gas-fitters and plumbers. The manometer or mercury gauge was connected by means of rubber tubing with the rectal tube on one side, and the rubber balloon on the other. The rubber balloon in which the hydrogen gas was collected held four gallons, and numerous experiments showed that when the gas was forced through the opening of a stop-

cock, the lumen of which was about the size of an ordinary knitting needle, a pressure upon the balloon equal to two hundred pounds (ninety kilograms) would never register more than three pounds (1.3 kilograms) of pressure to the square inch. The escape of air or gas from the rectum was prevented by an assistant pressing the margins of the anus against the rectal tube. I will give an account of only a few of the experiments to illustrate this part of our subject.

*“Experiment 15.*—Dog, weight thirty-five pounds (16 kilograms). Immediately after death the lower portion of the rectum was isolated and the rectal tube inserted and fixed in its place by tying a string firmly around the rectum. The abdomen was opened and the intestines left *in situ*. The ileum was cut transversely six inches above the ileo-cæcal valve and a glass tube inserted into the distal end, which was also tied in. Hydrogen gas was inflated from a rubber balloon. Under a pressure of three-quarters of a pound (.3 kilograms) the cæcum dilated, and a moment later the gas escaped from the gas tube and was ignited. The flame remained steady under a pressure of from one-half to three-quarters of a pound (.2 to .3 kilograms).”

*“Experiment 25.*—Dog, weight eighteen pounds (8 kilograms). Rectal insufflation of hydrogen gas, the dog being fully under the influence of ether. The colon and cæcum were only moderately distended when the gas under one-quarter of a pound (.1 kilogram) of pressure passed the ileo-cæcal valve with an audible gurgling sound. Under one pound (.4 kilogram) of pressure the abdomen became uniformly distended and tympanitic, and when an elastic tube was introduced into the stomach the escaping gas was ignited and burned with a steady flame as long as the pressure was continued.”

*“Experiment 18.*—Strong, healthy young man. The subject was placed flat upon his back and

hydrogen gas was forced into the rectum from a rubber balloon; at first the gas was forced in very slowly under a pressure of one and a half pounds (.6 kilogram) which distended the colon visibly as far as the cæcum. As the distension appeared to remain the same the pressure was increased to two pounds (.9 kilogram), when suddenly the indicator of the manometer receded to one pound (.4 kilogram), and the umbilical region became prominent and resonant, showing conclusively that the ileo-cæcal valve had been rendered incompetent and that the small intestine was rapidly filling with gas. As soon as the whole abdomen had become distended and tympanitic, the manometer again registered one and one-half pounds (.6 kilogram) of pressure and remained at this figure for some time after further inflation was discontinued by turning the stop-cock."

This and other experiments prove that in a normal condition the resistance of the ileo-cæcal valve to rectal insufflation of hydrogen gas in a healthy adult person is overcome under a pressure of one and one-half to two and one-quarter pounds (.6 to 1.1 kilograms). This amount of pressure is not sufficient to injure the coats of a healthy intestine, and none of the persons experimented on suffered much pain or any other immediate or remote consequences from the insufflation.

As the result of numerous observations, I may state that when the inflation is made slowly and continuously there is less danger of injuring the intestines than when it is made rapidly, or with interruptions. Slow and gradual distension of the cæcum is best adapted to overcome the competency of the ileo-cæcal valve, by gradually stretching the valve until the margins become separated. It is absolutely necessary to relax the abdominal muscles completely by placing the patient fully under the influence of an anæsthetic. A rubber balloon holding from two to four gallons (10 to 20 litres) recommends itself as the



most efficient and the safest instrument for making rectal insufflation for therapeutic or diagnostic purposes.

*Inflation of the Stomach.*

It would be natural to expect that the alimentary canal could be inflated with more ease and with less force by following the direction of the normal peristaltic wave. That this is not the case was abundantly shown by the experiments which I made. These experiments demonstrated conclusively that it is more difficult to inflate the alimentary canal from above downwards, than from below upwards ; as in the living animal I succeeded in only one instance in forcing hydrogen gas from mouth to anus, while in others an amount of force sufficient to rupture the peritoneal coat of the stomach, only effected distension of the stomach and upper portion of the intestinal canal. It is evident that great distension of the stomach constitutes an important factor in causing or aggravating intestinal obstruction, as it results in compression of the intra-abdominal organs, which may give rise to impermeability of the intestines, or may aggravate conditions arising from an existing partial obstruction by producing sharp flexions among the distended coils of intestine.

For diagnostic and surgical purposes the stomach can be readily inflated to almost any extent through a stomach tube, and when it becomes necessary to ascertain the presence of a visceral wound of the stomach, this method of inflation should be invariably practiced. Perforations in the posterior wall of the stomach, and in the region of the pyloric orifice, are not easily found by the ordinary methods of examination, while their existence and exact location can be determined in a few seconds, and with certainty by this simple procedure.

A number of successful operations for gunshot

wounds of the stomach has been reported where one bullet produced two perforations; both perforations were discovered and closed by suturing, and the patients recovered. I have knowledge of two cases where one perforation was overlooked and the patients died of peritonitis, which could be traced to the unsutured perforation. In one of these cases a bullet passed through the cardiac extremity of the stomach in an antero-posterior direction. The perforation in the anterior wall was readily found and sutured, and as no other visceral injuries could be found the operation was completed. The patient died of septic peritonitis on the second day. The necropsy revealed a second perforation in the posterior wall of the stomach, and a septic peritonitis which had plainly developed from this source, as the large opening had remained patent, establishing a free communication between the interior of the stomach and the peritoneal cavity.

The second case is reported by Dr. Ohage, of St. Paul, Minn., and is of great interest, as one bullet produced three perforations in the stomach. The bullet passed transversely through the upper part of the abdominal cavity. Abdominal section was made, and two perforations in the stomach, one near the cardiac extremity, the other near the pylorus, were easily found and sutured. The surgeon had every reason to believe that he had sutured all of the perforations. The patient died of septic peritonitis, which, as the post-mortem showed, was caused by an overlooked perforation in the small curvature of the stomach. In both of these cases it would have been easy to discover the undetected perforation, had the stomach been inflated after suturing the perforations, which were found without this diagnostic test.

*Hydrogen gas being the lightest body known, non-toxic, non-irritating, and possessing valuable inhibitory antiseptic properties, is the most suitable*

*substance for ballooning the stomach or intestines for diagnostic purposes.* Pure hydrogen gas made by using pure zinc and sulphuric acid is non-toxic, and when injected into large serous cavities, as the abdominal and pleural cavities, it produces no local irritation, and is absorbed in a short time. I made a number of experiments on dogs by injecting large quantities of the pure gas into the peritoneal and pleural cavities and into the subcutaneous cellular tissue, and examination of the tissues after the absorption of the gas always showed them to be in a normal condition. Pure hydrogen gas is not only a harmless aseptic substance, but it also possesses at least indirect antiseptic properties. The only pathogenic microbe which is known to be capable of reproducing itself upon a proper nutrient medium in an atmosphere of hydrogen gas is the bacillus tetani; most pathogenic microbes require a certain amount of oxygen for their growth and reproduction besides the nutrient medium.

Inflation of the peritoneal cavity with hydrogen gas, may prove to be one of the means of preventing septic peritonitis in cases in which the hydrogen gas test is applied in the treatment of gunshot wounds of the stomach and intestines. There is absolutely no danger of causing an explosion in lighting the gas as it escapes from a perforation in the abdominal wall or from the end of a small glass tube. The smallness of the openings in the instances just cited will be a sufficient safeguard against an explosion. As a matter of course, ignition of a large volume of hydrogen gas should be carefully avoided, as such an occurrence would cause an explosion.

*Hydrogen Gas Test as Applied in the Diagnosis of  
Perforating Gunshot Wounds of the Abdomen.*

I have up to the present time applied this test in over one hundred cases of gunshot wounds of the abdomen intentionally produced in dogs, and

in every instance where the stomach or intestine was wounded, the visceral complication was positively diagnosed before the abdomen was opened; hence I have no reason to make any retraction from the claim previously made, that the test is infallible in making a positive differential diagnosis before abdominal section is made, between a simple penetrating gunshot wound of the abdomen and a penetrating wound complicated by visceral wounds of the gastro-intestinal canal.

In all these experiments the animal was strapped on one of Pasteur's operating tables, the abdomen shaved, and after the animal was fully under the influence of an anæsthetic, the shooting was done with a 32-calibre revolver. Rectal inflation of hydrogen gas was practiced immediately after the shot was fired, and after its diagnostic indications were carefully studied and noted, the abdomen was opened and its contents examined for visceral injuries. In all cases where the colon was perforated, inflation could be done under very slight pressure, as the gas readily escaped into the peritoneal cavity and from there through the wound of entrance, where it was ignited as it escaped. If the perforation of the intestine was located above the ileo-cæcal valve, more pressure was required, as the resistance offered by the ileo-cæcal valve had to be overcome before the small intestine could be inflated. I will cite only one of the many experiments.

*"Experiment 65.*—Dog, weight twenty-five pounds. Under full anæsthesia the animal was shot in the abdomen, the bullet passing nearly in a transverse direction through the abdominal cavity, an inch and a half below the umbilicus, the points of entrance and exit being midway between the linea alba and spine. Rectal insufflation of hydrogen gas made under very low pressure was followed by rapid distension of the abdomen, an occurrence which furnished strong



evidence that the gas escaped through a perforation of the colon into the peritoneal cavity. The gas escaped at once from the wound of entrance and when ignited burned in a steady blue flame. On opening the abdomen, gas-escaped from the peritoneal cavity, the small intestine was empty, and only a small quantity of gas was found in the colon. The following intraperitoneal injuries were found: Four perforations of the duodenum, two of the jejunum, and one of the cæcum, also a perforation nearly through the center of the left kidney, laceration of the receptaculum chyli, and a number of perforations in the mesentery. The bullet was found between the left kidney and the abdominal cavity."

In this experiment, as in all others of a similar nature, the gas escaped through the lowest perforation and accumulated in the peritoneal cavity until the intra-abdominal pressure became sufficient to force it through the perforation in the abdominal wall.

In using the hydrogen gas test in the diagnosis of perforating gunshot wounds of the abdomen it is of the greatest importance to observe carefully the effects of the inflation in changing the form of the abdomen. If the colon is perforated the gas will escape readily through the opening in the bowel under low pressure, probably not more than quarter to half a pound to the square inch. As the gas accumulates in the free peritoneal cavity the abdomen is at once uniformly distended and the free tympanites can be proved by absence of liver dulness. Even if gas should not escape through the external wound, its presence in the free abdominal cavity would be sufficient proof of the existence of intestinal lesions and would consequently be a convincing argument for the necessity of laparotomy.

If no intestinal complications are present, or if the visceral wound is located above the ileo-cæcal valve, this becomes apparent after insufflation has

progressed sufficiently to distend the entire colon, a condition which may be known to be present from the increased width of the abdomen and the area of tympanitic resonance over the distended organ. Auscultation over the ileo-cæcal region will enable the surgeon to tell when the resistance of the ileo-cæcal valve has been overcome, as this will be announced by a distinct and audible gurgling or blowing sound as the gas rushes from the colon through the opening caused by the mechanical separation of the margins of the circular valve into the ileum. As the loops of small intestine one by one become distended from below upwards with the gas, the hypogastric region first becomes prominent and tympanitic, and if no perforations are present, the abdomen becomes barrel-shaped from the distension due to dilated intestines. In this condition the liver is lifted upwards by the distended intestines, the dulness is not effaced as in free tympanites, but the area of dulness is carried higher up.

If the small intestine is perforated some distance from the ileo-cæcal region, the limited distension and tympanites in the hypogastric region caused by the distended intestinal loops below the perforation will soon be displaced by the free tympanites resulting from the escape of gas into the peritoneal cavity.

If the rules laid down in this paper for the treatment of penetrating gunshot wounds of the abdomen are followed, free tympanites will never occur, as the gas entering the peritoneal cavity from an intestinal wound will escape at once through the perforation in the parietal peritoneum which has previously been exposed by incision through the abdominal wall down to this point.

*A Clinical Contribution in Testimony of the Value and Reliability of the Hydrogen Gas Test in the Diagnosis of Penetrating Gunshot Wounds of the Abdomen.*

The following six cases of penetrating gunshot wounds of the abdomen have come under my personal observation since I have demonstrated experimentally the value of rectal insufflation of hydrogen gas in the diagnosis of traumatic perforations of the gastro-intestinal canal. In the treatment of these cases I relied implicitly upon the indications derived from the test.

*Case 1.<sup>2</sup> Gunshot Wound of Chest and Abdomen; Double Perforation of Stomach; Laparotomy; Death from Hæmorrhage and Shock.*—C. H., a man, seventy-two years of age, was brought to the Milwaukee Hospital by the police patrol, at 7 A.M., July 9, 1888, for a suicidal, bulldog pistol (44-calibre), wound of the chest, inflicted about two hours previously. Pistol held in the left hand, as ascertained from the patient and confirmed subsequently by examination of the direction of the bullet. The patient stated that he had pointed the pistol toward the heart.

*Examination, 7 a.m.*—Wound of entrance situated in the sixth left intercostal space, surrounded by emphysema. Seventh rib fractured at junction of cartilage and bone. No wound of exit. Patient conscious; complains of severe pain in the epigastric region, increased by pressure. Pulse rapid and weak; vomits and expectorates blood; area of liver dulness diminished. Percussion and respiratory sounds normal. No evidence of hæmo- or pneumothorax.

*9 a.m.*—Flexible tube introduced and stomach inflated with hydrogen gas from a four gallon rubber balloon. Gas escaped and ignited at the wound of entrance with an audible sound. Field of operation thoroughly disinfected. Patient etherized and laparotomy made by incision from the

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<sup>2</sup> The Medical News, Aug. 25, 1888.

ensiform cartilage to the umbilicus. The omentum and stomach were drawn forward into the wound. A large perforation, about one and a half inches in length (the large size being due to the oblique direction of the bullet), was found in the stomach, midway between the pylorus and the cardiac extremity, near the greater curvature. Stomach partially filled with coagulated blood. With the index finger introduced through this perforation, another was detected in the posterior wall near the lesser curvature. An opening was made in the lesser omentum, but on exploration of the posterior surface of the stomach, the second perforation could not be found. The blood-clots were removed from the stomach by irrigation through the lower wound.

For the purpose of finding the second wound the stomach was again inflated with hydrogen gas which was injected directly through the perforation. The gas escaped through the posterior opening in a continuous stream, which made it easy to locate the second perforation. The omental opening was enlarged by tearing, and the perforation was discovered on the posterior surface near the lesser curvature and close to the cardiac orifice. Great difficulty was experienced in dragging the stomach sufficiently forward and downward into the abdominal incision to enable me to suture the perforation, which was two inches in length. It was closed by a continued sero-muscular suture, the anterior perforation by Czerny-Lembert sutures. A large quantity of fluid and coagulated blood was found behind the stomach, in the region of the pancreas. Copious hæmorrhage had evidently taken place at both perforations as well as in the post-peritoneal space. The visceral wounds indicated that the bullet had passed from above downward, backward, and to the right.

At this stage of the operation the patient collapsed from the continued effect of shock and



hæmorrhage. The foot of the table was elevated, external heat applied, and a saline infusion to the amount of fifteen ounces was made into the left median basilic vein. Brandy was injected subcutaneously and the faradic current applied, but all these means proved fruitless, and the patient died from the combined effects of hæmorrhage and shock before the external wound could be sutured.

After death the abdominal incision was closed and inflation of hydrogen gas, *per rectum*, made to test the condition of the sutured perforations. A stomach tube was introduced and the gas, under a pressure of less than a pound to the square inch, was forced through the entire gastrointestinal canal and escaped through a small glass tube which had been inserted in the distal end of the stomach tube, where it was ignited and burned in a continuous flame as long as the pressure upon the rubber balloon was continued. This showed that both visceral wounds had been effectually closed and that no other perforations existed.

The necropsy, which was made at once, revealed that the bullet had entered the chest through the seventh rib near the junction with the costal cartilage, causing a comminuted fracture. The pleural cavity at this point was obliterated by adhesions. The bullet passed through the lower lobe of the left lung, after which it perforated the diaphragm and entered the abdominal cavity, passing through the cardiac extremity of the stomach from above downwards. Liver and spleen intact, upper margin of tail of pancreas lacerated. Bullet passed to left of the aorta, entered the left crus of the diaphragm, fractured the last rib at the neck and perforated the spinal column, entering between the last dorsal and first lumbar vertebræ, escaping through the body of the latter, fracturing at the same time its right transverse process. The bullet was found in the

subcutaneous connective tissue in the right lumbar region. The spinal canal was opened by the bullet in its passage through the vertebra, and loose fragments of bone lay in the canal. The membranes were intact and the cord itself not injured.

*Remarks.*—The location of the wound of entrance in this case did not indicate that the bullet had entered the abdominal cavity, unless the revolver was held in the left hand; in that case, if directed toward the heart, the track of the bullet would necessarily be downward, backward and from left to right. Taking it for granted that the bullet took this direction, it would still have been possible for the stomach to escape injury. The circumscribed emphysema around the external wound and the hæmoptysis, as well as the location of the wound, left no doubt that the lobe of the left lung was injured. The absence of hæmothorax and pneumothorax was explained by the post-mortem, as the left pleural cavity was found completely obliterated by adhesions. Under a pressure of not more than half a pound to the square inch, the hydrogen gas was forced from the stomach through the external wound, where it was lighted and burned in a large continuous flame until it was extinguished by compression with a large moist sponge, thus demonstrating positively the existence of perforations in the stomach.

Although the stomach can be inflated by rectal insufflation of hydrogen gas, the more direct method by using a stomach tube should have the preference in cases of perforating gunshot wounds of the abdomen where from the course of the bullet there exists a probability, or even a possibility, that this organ has been injured. Dr. Ohage's case serves as a warning to apply the test again even after suturing two perforations made by one bullet passing transversely through this organ,

for the purpose of detecting a third perforation should this exist.

*Case 2. Gunshot Wound of the Abdomen; Twelve Perforations; Laparotomy; Recovery.*<sup>3</sup>—J. J., a young man sixteen years of age, was out hunting on Sunday, September 9, 1888, with some companions, one of whom accidentally discharged his 22-calibre rifle at a distance of about one hundred and fifty feet, the bullet striking the patient in the abdomen. The injury caused but little pain, and immediately after the accident the patient walked about forty yards to a farmhouse where he was placed in bed. From there he was conveyed on a cot, in a farmer's wagon, to the hospital, some six miles distant. The accident occurred about noon, and he arrived at the hospital at 3 P.M.

*Examination.*—Patient complains of considerable pain in the abdomen; pulse 80 and soft; his general appearance indicates no serious injury. On undressing him, a bullet wound, with omentum protruding, was found two inches to the right of the middle line, and on a level with the anterior superior spine of the ilium. Left iliac region dull on percussion; and in right a cracked-pot sound was elicited on percussion. A rectal enema was administered, and was followed by a free fæcal discharge, without admixture of blood. (On washing the fæces afterward the bullet was found.)

*Operation.*—Ether, as an anæsthetic; thorough disinfection of abdominal wall; rectal insufflation of hydrogen gas, followed by the escape of bubbles of the gas, within a few seconds, at the wound of entrance, into which had been placed a hæmostatic forceps, the blades separated so as to render the canal patent. The gas was lighted, and after thorough cauterization of the wound by the flame it was extinguished by the application of a wet sponge.

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<sup>3</sup> The Medical News, November 10, 1888.

Laparotomy by median incision, eight inches in length from pubes upward. About a pint of fluid blood in the peritoneal cavity, and hæmorrhage continuing from mesenteric veins at two points of perforation on the mesenteric side of the bowel, and to a less extent from perforations of the mesentery; arrested by ligating *en masse*. Within a distance of four feet, near the middle of the ileum, were found ten perforations, two of which were at the mesenteric border; also four perforations of the mesentery. Another perforation of the bowel was found within four inches of the ileo-cæcal valve on the convex side of the intestine, making so far eleven in all. All were closed by Czerny-Lembert sutures. At two points the perforations were so close together that it was found necessary to invert half the circumference of the bowel on the convex side, thus producing considerable narrowing of its lumen.

Two hours had been consumed in arresting the hæmorrhage and closing the eleven perforations, and the patient at this time had become pulseless, and yet it was deemed absolutely necessary to determine beyond all doubt if any more perforations existed by repeating the rectal insufflation of hydrogen gas. On repeating this test it was found that gas escaped freely from the pelvic cavity, without reaching the ileo-cæcal region, showing that at least one more perforation was below this point. The sigmoid flexure was brought into the wound and compressed between the index finger and thumb. Insufflation was again followed by escape of gas, demonstrating that the perforation was below this point. Inch by inch the bowel was examined by this method in a downward direction, until a perforation was found in the anterior portion of the rectum at a point where the peritoneum covering its anterior wall is reflected upon the bladder. The perforation was rendered accessible to direct treatment by an assistant making traction on the



colon and by keeping the margins of the wound well retracted by means of a pair of Hegar's retractors. It was closed by five Lembert sutures, with the greatest difficulty, on account of its deep situation and the inadequate light, which was furnished by two candles. From the perforations in the ileum there escaped pieces of green apples and intestinal contents, and from that in the rectum fluid fæces.

The peritoneal cavity was freely irrigated with a one-third of 1 per cent. solution of salicylic acid. After completion of the peritoneal toilet, a Keith's glass drain was introduced in such a manner that the distal open end was placed opposite the sutured rectal wound, and the abdominal incision closed in the usual manner. Whiskey was freely administered hypodermatically during the operation and after its completion, as the patient remained pulseless for half an hour. Time of operation two hours and a half. The foot of the bed was elevated and dry heat applied to the extremities.

Reaction was established slowly, but although the temperature did not rise much above normal, the pulse remained between 120 and 144 for two days, and during this time the patient was delirious. After the second day pulse and temperature nearly normal. The drainage tube was emptied every three or four hours by aspiration with a syringe, to the nozzle of which a piece of rubber tubing was fastened. Second day normal passage from the bowels. On the fourth day a fæcal fistula formed at the site of drainage, which closed ten days later.

The patient left the hospital completely cured six weeks after his admission, and has remained in perfect health ever since.

*Remarks.*—The subjective symptoms in this case four hours after injury, and after transporting the patient a distance of six miles, furnished no indications whatever of the extent of the vis-

ceral injuries which were found and treated during the operation. The rectal insufflation of hydrogen gas at once rendered the diagnosis accurate and positive, and pointed out the necessity of abdominal section. Eleven perforations were found and sutured without much difficulty, but the last perforation, in the deeper portion of the pelvis, could not have been detected by any other means of diagnosis short of rectal insufflation. Had this perforation been overlooked, death from septic peritonitis would have been inevitable, as considerable fæces had escaped through the perforation into the peritoneal cavity.

Drainage was established in this case, not only on account of the fact that fæcal extravasation had taken place, but also for the reason that, owing to the difficulty in gaining access to the rectal wound, I feared that the suturing was not as perfect as it should be, and by proper drainage I wished to guard against possible extravasation into the peritoneal cavity. Subsequent events proved the necessity of this precaution.

*Case 3. Perforating Gunshot Wound of Abdomen; four Perforations; Peritonitis; Laparotomy; Death.*—J. E. (case of Drs. Gudden, Steele, and Gordon, of Oshkosh), eighteen years of age, was out target-shooting with a companion, who, while raising his 22-calibre rifle to his shoulder, accidentally discharged it; the bullet struck the patient in the abdomen. He was about forty feet distant, and almost directly facing his companion. When first seen by Dr. Gudden, within half an hour after the injury was received, he was suffering pain in the abdomen, was pale, covered with cold, clammy perspiration, and vomited frequently. He was placed in a carriage and conveyed to his home, a distance of two miles. During the journey, the severity of the abdominal pain was so increased by the motions of the carriage as to necessitate repeated stops.

I saw the patient, with the above-named physi-

cians, October 9, 4 A.M., twelve hours after the accident.

*Examination.*—The wound of entrance was found to be at the outer margin of the left rectus muscle, about one inch below the level of the umbilicus. Abdomen dull on percussion in left iliac region, pulse 140, temperature 100° F. Penetration of the abdomen was proved by the introduction of a grooved director, which was left in place during the insufflation of the hydrogen gas.

The patient was placed under the influence of chloroform, and during the operation the narcosis was maintained with ether. The abdomen was thoroughly disinfected, and rectal insufflation of hydrogen gas practiced to ascertain if any perforation of the intestine existed. Under a pressure of about half a pound to the square inch, and the use of one-quarter of a gallon of gas, in a few minutes the gas escaped along the groove of the director, and, on applying a match, ignited as it escaped. The flame was now extinguished by a moist sponge, and the abdomen opened by a median incision, five inches in length, extending from the umbilicus to near the pubes.

On exposing the peritoneum at the lower angle of the incision, through this membrane there was observed a structure closely resembling an over-distended bladder. That this structure was a distended bladder was improbable, as the boy had urinated before the anæsthetic was administered. The peritoneum was carefully incised between two forceps and divided upon a grooved director to the same extent as the external incision, and it was then discovered that what appeared to be an over-distended bladder was a coil of small intestine distended with blood to twice its normal size. The whole pelvic cavity was found to be filled with fluid blood. On withdrawing the small intestine, five perforations, within a distance of three feet, near the junction of the jejunum and ileum, were found; four occurred in pairs on the lateral

aspect of the bowel, and one at the mesenteric attachment. All the perforations were disproportionately large to the size of the bullet, and would easily admit the tip of the index finger. The intestine, at the point of injury, was covered with a thick layer of recent plastic lymph, and the parietal peritoneum presented all the evidences of a beginning diffuse septic peritonitis. The intestine, which was over-distended by blood-clots for about three feet, was emptied and irrigated with a one-third of one per cent. solution of salicylic acid, which was used for constant irrigation during the entire time required to suture the perforations, which were closed by Czerny-Lembert sutures.

Further examination disclosed four perforations of the mesentery, from two of which quite profuse venous hæmorrhage was still going on. The hæmorrhage was arrested by ligature *en masse*, by passing a needle, threaded with fine silk, through the entire thickness of the mesentery, on either side of the perforations.

Rectal insufflation of hydrogen gas was repeated, so as to ascertain if any other perforations existed, and the gas, after it had been gently forced beyond the highest perforation, was made to traverse the balance of the entire intestinal canal by drawing forward loops of the intestine and returning them as examined without further insufflation. This procedure was found entirely satisfactory and practical, as the gas, on account of its low specific gravity, readily entered the highest point in the prolapsed intestinal loop.

The abdominal cavity was irrigated with salicylic acid solution, numerous coagula removed, the toilet completed, a glass drain introduced into the pelvis, and the abdomen closed.

Duration of operation two hours. Patient collapsed, pupils greatly dilated, and almost pulseless in spite of repeated hypodermatic injections of brandy, which were administered when signs

of collapse became apparent, throughout the operation. Enema of a teacupful of warm water and two ounces of brandy. Foot of bed elevated and external dry heat applied.

In an hour and a half he rallied somewhat from the operation, but again sank and died at 3 P.M., eight hours after the completion of the operation.

*Post-mortem* eighteen hours after death (Drs. Steele, Gudden, and Gordon). Circumscribed peritonitis present at the time of operation, now diffuse; very little fluid in abdominal cavity; several small blood-clots in vicinity of transverse colon. The perforations were all securely closed, and the bullet was found in the soft tissues to the right of the spinal column, between the fourth and fifth lumbar vertebræ, and near the ascending colon. The bullet, though only of 22-calibre, was oblong, and may thus explain the unusually large size of the perforations.

*Remarks.*—This case, compared with the foregoing, furnishes a strong argument in favor of early operative interference in cases of gunshot or stab wounds of the abdomen in which the existence of visceral lesions can be demonstrated by rectal insufflation of hydrogen gas. In the first case, although twelve perforations were found and sutured, and fæcal extravasation had taken place, no evidences of peritonitis were found, and the patient recovered. In this case twelve hours intervened between the time the injury was received and the treatment by laparotomy, during which time a septic peritonitis had developed, the extension of which the operation did not arrest, and from the effects of which the patient died.

*Case 4. Penetrating Gunshot Wound of Abdomen; Hydrogen Gas Test used with Positive Result; Laparotomy; Two Perforations of Ascending Colon; Death from Peritonitis on fifth Day.*—This patient, a boy fourteen years of age, was shot in the abdomen by the accidental discharge of a 22-calibre rifle in the hands of his playmate, who was stand-



ing a few feet from him. The accident occurred September 23, 1889, at 5 o'clock in the afternoon. The physician who was first called probed the wound and ascertained that the bullet had entered the peritoneal cavity, and sent the boy at once to the Milwaukee Hospital for surgical treatment. No shock and no evidence of internal hæmorrhage.

Two hours later, after the necessary preparations had been made for laparotomy, the hydrogen gas test was applied, and as this yielded a positive result, the abdomen was opened at once. The wound of entrance corresponded with the umbilical depression, and from the position of the patient at the time the accident occurred and from the direction in which the bullet was discharged, I had reason to believe that the ball passed through the peritoneal cavity from the wound of entrance in a direction from left to right.

The abdominal cavity was opened by a median incision extending from the wound of entrance to near the pubes. A small quantity of hydrogen gas was found in the peritoneal cavity. The colon was moderately distended, and I had no difficulty in detecting a perforation about eight centimetres above the ileo-cæcal region. The visceral wound was on the same level with the parietal wound and on the side of the bowel towards the umbilicus. I expected to find the second perforation at a point opposite and on the same level, but the most careful examination failed to reveal its existence. I could find no extravasation or discoloration which would have assisted me in locating the second visceral wound, of the presence of which I was convinced.

To locate the second perforation I resorted to the following procedure: The colon was compressed above and below the perforation that I had found, and direct insufflation with hydrogen gas was made through the visceral wound. The gas escaped from behind the bowel, and the con-

tinued escape led me at once to the wound, which was located between the serous layers of the mesocolon and was completely hidden behind the anterior peritoneal layer. No fæcal extravasation was found before or after the insufflation. Nevertheless it was deemed advisable to flush the peritoneal cavity with warm sterilized water. After testing the remaining portion of the intestinal canal for additional perforations, the visceral wounds and the external incision were closed in the usual manner. A Keith's glass tube was inserted to secure drainage. The case progressed favorably for thirty-six hours, when evidences of diffuse septic peritonitis developed, which rapidly increased in intensity until the fatal termination, the fifth day after the operation. No post-mortem.

*Remarks.*—As the whole length of the gastro-intestinal canal was treated for additional perforations at the time of the operation, and none were found, we must take it for granted that the fatal peritonitis was caused by infection through the visceral wounds which were sutured, or through the operation wound, or possibly, the septic micro-organisms were conveyed into the peritoneal cavity by the bullet. The most interesting feature in this case is the procedure which was employed to discover the second perforation. The ordinary methods of examination proved utterly inadequate to discover the second visceral wound. Direct insufflation through the perforation which had been found, at once revealed the existence and location of the second visceral wound. Before the perforations were sutured, the colon below the wound was emptied of its gas, and the remaining portion of the gastro-intestinal canal was tested for additional perforations by direct insufflation through the anterior visceral wound.

This modification of the ordinary method of applying rectal insufflation of hydrogen gas in the diagnosis of perforations of the gastro-intestinal canal offers great advantages in that it pre-

vents undue distension of the intestines, and when properly used renders it almost impossible to overlook a perforation sufficiently large to require direct surgical treatment. In cases of multiple perforations of the intestinal canal the lowest perforations can be readily located by rectal insufflation, but the remaining perforations should be pointed out by direct insufflation through the visceral wounds, taking the precaution to empty the sutured portion of the bowel of its gaseous contents, and after disinfection, if this becomes necessary, to return it into the abdominal cavity, thus preventing undue distension and extensive eventration.

*Case 5. Penetrating Gunshot Wound of Abdomen; Inflation of Stomach and Colon with Hydrogen Gas; Foreign Body in Peritoneal Cavity; No Visceral Injuries Demanding Surgical Treatment. Recovery.*—W. G., boy six years of age, was shot while he was standing on a box behind a saloon counter, the umbilicus reaching a little above the level of the counter. A bulldog pistol of 38-calibre was accidentally discharged at a distance of four feet from him. The bullet struck the counter to his left and in front, glanced, and penetrated the abdominal wall half an inch to the left of the linea alba and an inch and a half above the level of the umbilicus. After the shooting, the boy walked into an adjoining room without assistance, and the fact of his being seriously injured was only discovered on removal of his clothing. No shock. The patient complained of pain in the abdomen and vomited once, an hour and a half after the accident. The patient had eaten a hearty supper shortly before he was shot. No blood in the material vomited. Dr. Jürgens, the attending physician, applied a temporary antiseptic dressing over the wound, and administered small doses of morphia and atropia hypodermatically.

The accident occurred at 7 P.M., March 18,

1890, and on my arrival, seven hours later, his condition was as follows: Pulse 110 and full; face flushed, and although very quiet, complains of pain in the abdomen; liver dulness normal, both as regards location and extent. Wound of entrance plugged with omentum. The presence of omentum in the wound left no doubt that the bullet had entered the abdominal cavity, and from the location of the wound of entrance, and the probable course of the bullet from left to right and from below upward, I suspected that either the transverse colon or stomach had been perforated. Preparations were at once made for a laparotomy, so that in the event that the hydrogen gas test should yield a positive result the necessary operation should be done at once.

After the patient was thoroughly under the influence of chloroform, rectal insufflation of hydrogen gas was made, but when the colon had become fully distended it was discovered that the rubber balloon was leaking badly, consequently through insufflation could not be made. The insufflation of the colon, however, showed that this portion of the intestinal canal had escaped injury. The stomach was now inflated, and as this organ was fully distended without any leakage taking place, I was satisfied that no perforation existed. It still remained to determine whether the upper portion of the small intestine was injured, consequently an incision three inches in length, in the line of the wound of entrance, was made for the purpose of exploring the upper portion of the abdominal cavity for visceral injuries which might not have been revealed by the insufflations. A small shred of underclothing was found between the omentum and abdominal wall, near the track made by the bullet. After displacing the omentum upwards and to the left, a number of feet of the small intestine from the pylorus downward were examined with negative results. After a brief search, the bullet was found embedded in

the space between the tenth and eleventh ribs on the right side, half way between the costal arch and the spine. The bullet was extracted through an external incision after pressing it outward with the index finger in the abdominal cavity. Only a small quantity of blood was found in the abdominal cavity. One external incision was closed in the usual manner, with the exception of a space for a small strip of iodoform gauze, which was inserted in the track of the bullet as far as the peritoneum. Ordinary aseptic dressing, retained in position by broad strips of adhesive plaster. The patient recovered promptly from the immediate effects of the operation, but soon developed symptoms of circumscribed peritonitis which lasted for a number of days, after which he recovered rapidly and completely. The external wound suppurated for a short time.

*Remarks.*—This case is of great interest, as it was demonstrated at the time of operation that the bullet had passed at least six inches obliquely through the upper portion of the abdominal cavity without inflicting any visceral injuries which required surgical treatment. The insufflations, although imperfect on account of a defective rubber balloon, proved of great value, as they made a direct examination of the stomach and colon for perforations unnecessary. The bullet undoubtedly passed between the transverse colon and the pyloric extremity of the stomach on its way from the point of entrance to the tenth intercostal space.

It is a comparatively easy task to find the perforations after the abdomen has been opened, if they are located in the small intestine, but perforations of the stomach and colon are often overlooked during an ordinary examination, while their existence in these localities is promptly and infallibly revealed by insufflating these organs with hydrogen gas.



*Case 6. Perforating Gunshot Wound of Abdomen; Through Insufflation with Hydrogen Gas Showing no Intestinal Perforations; Wound of Left Kidney; Expectant Treatment; Recovery.*—S. W. A., thirty years of age, railroad conductor, was accidentally shot at 8 o'clock on the evening of April 3, 1890. The weapon used was a 22-calibre revolver. The physicians who were called were of the opinion that the bullet had entered the abdominal cavity, and advised prompt surgical treatment. An antiseptic compress was applied over the wound and morphia given hypodermatically. Almost immediately after the injury was inflicted the patient complained of a distressing pain in the region of the left kidney. No shock, or any other symptoms indicative of the existence of serious visceral injuries. Patient, accompanied by his physician, was transported on a cot by rail a distance of twenty-one miles, and arrived at the Milwaukee Hospital at 11:30 the same evening. At the hospital preparations had been made in the meantime for laparotomy.

*Present Condition.*—The wound of entrance was found near the tip of the cartilage of the seventh rib on the left side. The ragged opening, large enough to admit the little finger, was surrounded by numerous powder marks, showing that the shot was fired at very close range. Considerable emphysema in the immediate vicinity of the wound. Patient complains of pain in the wound and in the left lumbar region. Face flushed, pulse 90 and full; temperature normal. A small dose of atropia was given hypodermatically before chloroform was administered.

The abdomen and external wound were thoroughly disinfected. The track of the bullet was followed down to the peritoneal opening by an incision about three inches in length, which proved that the bullet had entered the peritoneal cavity. Under profound narcosis rectal insufflation of hydrogen gas was made. The colon

became fully distended before the gas passed through the ileo-cæcal valve, showing that no perforations existed in this portion of the intestinal canal. The gas rushed through the ileo-cæcal opening with a distinct gurgling sound, after which the hypogastric region became prominent and tympanitic. The distension of the abdomen gradually ascending as the insufflation advanced, proved that the intestines were intact; finally, when the stomach became distended, an elastic tube was introduced, into the distal end of which a small glass tube was tied. As soon as the tube reached the stomach, gas escaped and was repeatedly lighted at the end of the glass tube. The hydrogen gas test had furnished positive evidence of the absence of intestinal perforations, and as there appeared to be no danger from internal hæmorrhage, it was decided to pursue a conservative course of treatment. The ragged, discolored tissues lining the track made by the bullet through the abdominal wall were carefully dissected out, and the wound united with buried and superficial sutures, leaving a small space in the lower angle for drainage.

After the completion of the operation a catheter was introduced into the bladder, and a considerable quantity of bloody urine escaped. It was now evident that the bullet had injured the left kidney and that it was probably lodged in the tissues behind the organ. As the patient did not show any evidence of internal hæmorrhage, I concluded to await further developments in reference to the treatment of the kidney injury.

The urine contained blood in gradually diminishing quantity for two days, after which it remained normal both in quality and quantity. No untoward symptoms appeared, and the patient was fully convalescent and left the hospital two weeks after admission. He has since followed his occupation, and has suffered no inconveni-

ences whatever from the presence of the bullet in the lumbar region.

*Remarks.*—The hydrogen gas test in this case proved a perfect success, as the through insufflation demonstrated in a most positive manner the absence of intestinal perforations. The bullet must have passed between the cardiac extremity of the stomach and the splenic flexure of the colon on its way through the abdominal cavity to the left kidney. Without the hydrogen gas test it would have become necessary to make an abdominal section and examine the whole length of the gastro-intestinal canal in order to show that no perforations were present, a procedure which might in itself have proved a cause of death.

The belief is almost general that a gunshot wound of the kidney should be treated by nephrectomy. In this case I decided to pursue an expectant plan on account of the small calibre of the bullet, the absence of symptoms indicative of serious internal hæmorrhage, and the existence of only a moderate hæmaturia. It was my intention, in case the injury of the kidney should result in a suppurative inflammation of this organ or its surrounding tissues, to make subsequently a lumbar nephrotomy or nephrectomy.

#### *Objections to the Hydrogen Gas Test.*

Like all other departures from the old and time-honored methods of diagnosis and treatment, the use of the hydrogen gas test in the discovery of visceral lesions of the stomach and intestines in perforating gunshot wounds of the abdomen will have to run the gauntlet of adverse criticism until, after a more extended experience in the hands of different surgeons, its merits will more generally be recognized. The principal objection, and the one that has so far been mentioned most frequently, is that:

1. *Rectal Insufflation of Hydrogen Gas in the Diagnosis of Perforating Gunshot Wounds of the*

*Abdomen Increases the Danger from Fæcal Extravasation.*—The small intestines, even during active digestion, contain only a limited quantity of chyle, and in the numerous experiments on animals I have never observed that the gas forced out through the perforations any of the fluid or solid intestinal contents. Any one who has observed the process of inflation *ad oculum* will understand why it does not produce extravasation. Hydrogen gas being of much lower specific gravity than the fluid intestinal contents, lifts the distended intestinal loop to the highest possible *niveau* compatible with the mesenteric anchorage of the bowel; hence when the gas reaches a perforation, that portion of the intestine occupies a higher plane than the adjacent portions of the intestine, and the chyle by its own weight seeks a lower level, leaving the perforated part of the bowel empty of its normal contents as long as it remains distended with the gas. A number of experiments were made for the special purpose of showing that the fear of fæcal extravasation taking place on applying the hydrogen gas test in the diagnosis of visceral wounds of the gastrointestinal canal is unfounded. This will be shown most conclusively by the few experiments which I will detail briefly below.

The dogs used in these experiments had all had a full meal from three to four hours previously. Immediately after they were killed the abdomen was opened, and wounds corresponding in size with wound made by a 22-calibre bullet were made in different parts of the intestine before rectal insufflation was commenced.

*Experiment 1. Duodenum.*—Three wounds were made in this part of the bowel some distance apart, one on the free or convex side, one on the mesenteric side, and the third on the side at a point half way between the free and mesenteric borders. In a few seconds after the insufflation was commenced the gas had ascended as far as

the duodenum and escaped from all the openings freely without causing a drop of extravasation, although this portion of intestine contained a considerable quantity of fluid at the time.

*Experiment 2. Jejunum.*—Three openings were made in this part of the small intestine large enough to insert the tip of the little finger. The perforations were diminished in size, but not closed, by bulging of the mucous membrane. The gas reached the perforations after moderate distension of the intestine on the distal side, and escaped freely from all the perforations without causing a trace of extravasation.

*Experiment 3. Ileum.*—Similar experiment with same result.

*Experiment 4. Cæcum.*—An opening large enough to insert the tip of the little finger was made in the anterior wall of the cæcum, and although this part of the bowel contained liquid fæces, the gas did not force out any of the contents.

*Experiment 5. Ascending Colon.*—In this experiment the opening, similar in size, was made on the side of the bowel, but the escaping gas caused no extravasation.

*Experiment 6. Transverse Colon.*—Same experiment with same result.

*Experiment 7. Sigmoid Flexure.*—Lateral perforation large enough to correspond with a wound made with a 38-calibre bullet through which gas was forced by rectal insufflation, but no fæces escaped. Fæcal extravasation occurred when the bowel was compressed above the perforation and the insufflation was continued.

These experiments only corroborate my observations made in over a hundred perforating gunshot wounds of the abdomen in dogs, and my clinical experience that the distension of wounded intestines with hydrogen gas does not increase the danger from fæcal extravasation. The escape of solid fæces through a perforation by insufflation of gas is not to be expected, as the gas will pass



between the solid mass and the intestinal wall, lifting the perforation away from the intestinal contents.

2. *Rectal Insufflation of Hydrogen Gas does not Infallibly Demonstrate the Existence of Visceral Wounds of the Stomach or Intestines.*—I have already stated that the hydrogen gas test has proved infallible in my hands, both in my experimental work and in the six cases which I have reported in this paper. There are two conditions under which hydrogen gas might pass the whole length of the gastro-intestinal canal without indicating the existence of a perforation:—(a) Plugging of the opening by a foreign body; (b) The perforation may be too small for the escape of the gas.

(a) *Plugging of Perforation by Foreign Body.*—Failure of the test from this source could only take place in exceptional cases, as when the stomach is wounded soon after the ingestion of a meal. A case has been reported where the stomach contained coarse solid food, in which the test resulted negatively. The patient died and the post-mortem showed that the perforation was closed by grains of rice which the patient had eaten shortly before he was shot. It is impossible to say whether in this particular case the foreign substance was driven into the opening by the bullet, or whether it was forced into it by the inflation. To prevent the latter occurrence in gunshot wounds of the stomach it is absolutely necessary to either evacuate the stomach by an emetic shortly before the test is applied, or to place the patient in such a position during the inflation that the wound in the stomach will occupy the highest level, as when this is done the hydrogen will lift the perforation away from the solid contents and thus effectually prevent plugging of the perforation. If the location of the probable wound is not known, the patient should be placed alternately in different positions during

the insufflation. If, from the course of the bullet it is probable that the stomach has been wounded the inflation should not be made *per rectum*, but directly through a stomach tube, as inflation of this organ can be made more effectually by this direct method.

There is absolutely no danger that mechanical closure of the perforation by the impaction of a foreign body will ever interfere with the reliability of the hydrogen gas test in gunshot wounds of the intestines.

(b) *Small Size of Perforation*.—In every case of gunshot wound of the stomach or intestines, the size of the perforation is diminished by eversion of the mucous membrane which either partially or completely plugs the opening. The permeability of the perforation will not only depend on the size of the opening, but it is also influenced by the thickness of the wall of the organ at the seat of injury. The wall of the intestinal canal diminishes in thickness gradually from the stomach downward to the ileo-cæcal region. A bullet wound of the stomach of the same size as one in the lower portion of the ileum will be more securely closed spontaneously by prolapse of mucous membrane, and will consequently be less likely to be permeable to the escape of gas when insufflation is practiced.

I made an extensive series of experiments on dogs with missiles of small calibre, both for the purpose of determining the size of perforation which makes laparotomy necessary and also to ascertain the size of the visceral wound which will permit the hydrogen gas to escape into the peritoneal cavity when insufflation is made for diagnostic purposes. In reference to the first point my experiments demonstrated conclusively that the size of the missile is absolutely no indication of the size of the perforation. I used missiles varying in size from a No. 8 shot to a 22-calibre bullet. Cartridges containing an ordinary charge

of powder were loaded with from four to twelve shot and the shooting was done with an ordinary 12-gauge single barreled shot-gun at a distance of ten feet, with the dog strapped upon a table and placed in erect position, and the umbilicus for a central mark. Shot of all sizes invariably penetrated the abdominal wall and passed through the peritoneal cavity. A record was kept of the exact location of the wounds of entrance and of the number of shots which entered the peritoneal cavity in each case. A number of the animals died within half an hour to two hours after the shooting and the necropsy invariably revealed hæmorrhage as the immediate cause of death, the shot having injured some of the large abdominal vessels or vascular organs, as the spleen, liver or kidneys. Death from this cause occurred less frequently if shot of fine calibre was used, yet in several instances it was found that No. 8 shot, which are not larger than a mustard seed, caused death from hæmorrhage when the inferior vena cava or one of its large branches was injured.

A number of dogs recovered without treatment after having been shot transversely through the abdomen with a 22-calibre conical bullet. These animals were killed from one to several weeks after the shooting, when from one to four healed perforations were found. The point of perforation always presented the same characteristic appearance, a nipple-like elevation on the serous surface and a corresponding conical depression on the mucous surface. What occurred in these cases was temporary closure of the perforation by plugging of the visceral wound with mucous membrane and the formation of a cover of new tissue over the apex of the prolapsed mucous membrane. Dogs that were wounded with shot finer than No. 4 seldom died from the effects of the visceral injuries, and some of these animals were shot three different times at intervals of one to two weeks, producing in this way dozens of minute perforations in

different portions of the gastro-intestinal canal, all of which healed without surgical or any other treatment. In the animals that died from the visceral injuries the necropsy always showed the existence of perforations larger than are ordinarily produced by a 22-calibre bullet. These large perforations were either caused by two shots passing in close proximity through an intestinal loop making one common wound, or they were the result of a laceration caused by the shot grazing the convex margin of an intestinal loop. In this manner I have seen a No. 2 shot tear an opening in the bowel large enough to insert the tip of the index finger.

The next object in this series of experiments was to determine the size of the smallest wound of the stomach or intestines which could be discovered by means of the hydrogen gas test without opening the abdomen. The test was applied in perforating wounds of the abdomen inflicted with shot varying in size from No. 8 to "B.B.," the latter of which corresponds with an 18-calibre bullet. Rectal insufflation was practiced immediately after the shooting. All animals in which the hydrogen gas test gave a positive result died, that is, if the gas escaped either through one of the perforations in the abdominal wall, or if it escaped into the peritoneal cavity in sufficient quantity to be recognized by physical symptoms, such as free tympanites, as nothing was done in the way of treatment in all of these cases. The post-mortem invariably showed a perforation or laceration of the intestines or stomach too large to become temporarily closed with a plug of mucous membrane; hence infection of the peritoneal cavity and death from septic peritonitis followed in from one to three or four days.

In the animals in which the test resulted negatively, and these included some in which shot of large calibre were used, peritonitis did not ensue, and if hæmorrhage did not prove a source of dan-

ger, they recovered without any untoward symptoms.

This to me proved an object of great interest and far-reaching practical value, as it satisfied me that the hydrogen gas test can not only be relied on when it is necessary to interfere in cases of perforating gunshot wounds of the abdomen, but that it also furnishes the only safe and positive indication for non-interference.

In all cases where the test resulted negatively, the insufflation was continued until the gas escaped from the elastic tube which was inserted into the stomach, and the presence of the escaping gas was demonstrated by lighting it at the end of the tube. I have frequently had opportunities to observe that perforations made with a 18-calibre shot were impermeable to the insufflation and that occasionally considerable force had to be used to make the gas escape through a wound made with a 22-calibre bullet. These are the perforations which will heal spontaneously and through which infection of the peritoneal cavity is not likely to occur, because escape of the gaseous and liquid contents of the intestines does not occur.

3. *The Hydrogen Gas Test Renders Reduction of Intestines after Laparotomy more Difficult or Impossible.* — This objection can only apply to cases of wounds of the stomach or of the upper portion of the small intestine. I have already insisted that when, from the course of the bullet, we have reason to believe that the stomach has been injured, this organ should be inflated directly through an elastic tube and not by rectal insufflation. If the test results positively, the indication for a laparotomy has been furnished; if otherwise, the nearest hollow organ, the colon, is examined for perforations by rectal insufflation. In the absence of perforations below the ileo-cæcal valve, the insufflation is extended as far as the stomach, and if the result is positive and the per-



foration is located high up in the intestinal canal, the intestines below the first perforation will be found moderately distended upon opening the abdomen. After the last perforation has been found, much of the gas can be evacuated through this opening. By resorting to Kiimmels's method of replacing the intestines, no difficulty is experienced as a rule in this step of the operation. In all of my cases, and in all of my experiments I have invariably succeeded in replacing the intestines without much loss of time and without doing any damage. If high insufflation has been made and if after suturing all of the perforations, any difficulty should be experienced in replacing the intestines, there should be absolutely no objection to making a small incision into one or more of the most distended loops of the inflated intestine and after evacuating the gas closing then by one or two superficial sutures.

4. *Hydrogen Gas Test is Unnecessary.*—It has been asserted that the hydrogen gas test is superfluous because every perforating gunshot wound of the abdomen is necessarily complicated by visceral injuries which require treatment by laparotomy. This objection to the use of the hydrogen gas test has already been disposed of, as I have shown experimentally and clinically that in a fair percentage of cases of perforating gunshot wounds of the abdomen the bullet inflicts no serious visceral injuries, and that such cases will recover, as a rule, without laparotomy.

It has also been stated that the use of the hydrogen gas test is unnecessary in detecting the perforations after the abdomen has been opened, as it is claimed that the perforations could be readily found by examining the intestinal loops lying in the course of the bullet. The adoption of this advice could not fail to lead to frequent errors of diagnosis and disastrous results in treatment, as the injured part of the bowel changes

its relative position in the abdominal cavity very soon after the injury has been inflicted. This is especially true of that portion of the small intestine supplied with a long mesentery.

In order to show that a perforated intestinal loop will in a short time wander away from the place it occupied when struck by the bullet, I made the following experiments:

*Experiment 1.*—Medium sized male dog. The abdomen was opened by a median incision, exactly four inches in length; the omentum pushed to the left of the median line and sutured to the left margin of the abdominal wound. The intestines being disturbed as little as possible, two points of intestine corresponding exactly to the upper and lower angles of the incision were marked by drawing a black thread through the serous coat which was loosely tied and cut short. The external incision was sutured and the dog was killed eighteen hours afterwards. The wound was found firmly agglutinated and the omentum adherent to the incision. Enlarging the incision and leaving the intestines undisturbed, the upper marked loop of the intestine was found displaced two inches to the right of the median line and one inch and a half downwards and backward, being also covered by another intestinal loop, and the thread being directed toward the spine. The lower marked point was found one and one-half inches to the left, and one and one-fourth inches downwards, behind the bladder with the thread also directed towards the spine.

In the three subsequent experiments, the abdominal incision was made fully six inches in length and the omentum was left undisturbed, and in the middle line two loops of the intestine, four inches apart, were marked, one with a white, and the other with a black thread which were passed through the serous coat and loosely tied. The intestines were exposed by a rent in the

omentum four inches in length. On the margin of the abdominal incision a small transverse cut in the skin was made to indicate the exact position occupied by the marked intestinal loops.

*Experiment 2.*—Large female dog. Experiment described as above. Animal killed after twelve hours. Abdomen opened by incision from sternum to pubes and transversely at level of umbilicus. The lower marked loop was found displaced upwards three inches, and half an inch to the right of the median line. Thread in same direction as when introduced. Upper loop displaced downwards two inches, thread directed laterally, covered by another loop of intestine.

*Experiment 3.*—Large male dog. Killed six hours after marking position of intestinal loops. Examination showed that the marked points were transposed, upper loop now being the lower, displaced four inches downwards and half an inch to the left of the median line. Lower loop displaced two inches upwards and buried underneath two layers of intestinal coils.

*Experiment 4.*—Large female dog. Killed two hours after opening the abdomen. Upper marked point displaced an inch and a half downwards and an inch to the left of the median line, and covered by a loop of intestine; lower loop displaced one inch downward, and was pushed half an inch to the left of the median line.

These experiments show conclusively that in making laparotomy for perforating wounds of the abdomen, the wounded intestinal loops are seldom found in the position they occupied at the time they were hit by the bullet. Even two hours after the injury an intestinal loop perforated when it occupied a place corresponding with the level of the umbilicus may be found in the cavity of the pelvis, or several inches above and to the left or right of the median line.

The hydrogen gas test is of the greatest value in locating the perforation after the abdomen has

been opened, as without it, one or more perforations may be overlooked and become a cause of death in cases that might have recovered had the perforations been discovered and sutured. From the inaccessibility of the duodenum perforations of this part of the intestinal canal are very liable to be overlooked. Two cases have recently been reported where this occurred. Bernays, of St. Louis, made a laparotomy for perforating gunshot wound of the abdomen, sutured several perforations, and overlooked, as the post-mortem showed, a large perforation of the duodenum.

The second case is related from the clinic at Basle. A man was brought into the hospital with a penetrating stab wound of the abdomen. The wound was enlarged sufficiently to permit of eventration. Inch by inch the small intestine was examined, but no perforation was found. The man died of septic peritonitis two days later. The post-mortem revealed a wound of the duodenum over an inch in length which had been overlooked, and which was the direct cause of the peritonitis and the indirect cause of death. It is needless to say, that had the hydrogen gas test been applied in these cases before or after the abdomen was opened, the perforations would have been discovered and sutured, and in all probability, both patients would have recovered.

In all cases of perforating gunshot wounds of the abdomen the whole length of the gastrointestinal canal should be tested by ballooning the stomach and intestines before the abdomen is closed, in order to guard against the possibility of leaving an undiscovered perforation.

## *2. Treatment of Gunshot Wounds of the Stomach and Intestines.*

The propriety of surgical interference in cases of gunshot wounds of the stomach and intestines will depend on one of two things :

1. Dangerous internal hæmorrhage.

2. Visceral wounds of the stomach or intestines large enough to permit of extravasation and the escape of hydrogen gas on applying the diagnostic test.

Alarming intraperitoneal hæmorrhage furnishes an urgent indication for treatment by laparotomy irrespective of the existence of the visceral lesions of the gastro-intestinal canal. In these days of aggressive surgery it would indeed be unjustifiable to permit a patient to die slowly but surely from hæmorrhage from an intra-abdominal wound which in itself is amenable to successful treatment by prompt surgical means.

The signs and symptoms of profuse internal hæmorrhage come on soon after the injury has been inflicted, and are so plain and significant that they can hardly be misinterpreted even upon a brief and superficial examination. The progressive acute anæmia, the conditions of the pupils and pulse, and the complexus of nervous symptoms which attend alarming internal hæmorrhage present a clinical picture which, when once seen, is never forgotten and always recognized.

In such cases no time should be lost in looking for evidences of the existence of wounds of the gastro-intestinal canal, or in applying the hydrogen gas test, as the prime and most urgent indication is to gain access to the bleeding vessels by opening the abdomen in the median line, and then to arrest the hæmorrhage at once by compression until the bleeding points can be secured by ligation or the antiseptic tamponnade. After the hæmorrhage has been arrested, the whole gastro-intestinal canal, or such part of it as, from the course of the bullet, is known to have been exposed to injury, is tested by insufflation of hydrogen gas for the purpose of ascertaining in as short a time as possible, the existence, location and number of perforations.

In cases in which, on account of the absence of



dangerous hæmorrhage, the symptoms are less urgent, it is important to determine the necessity of treatment by laparotomy by resorting to the hydrogen gas test for the purpose of diagnosing the existence and size of perforations of the gastro-intestinal canal. If through insufflation can be made, it is proof positive that no perforations exist, or, if present, that they are too small for extravasation to occur, and in the absence of other indications for abdominal section it is advisable to pursue a conservative course of treatment. Such patients are given an opiate to diminish the peristaltic action of the bowels; an absolute diet is ordered and rest in bed enforced for at least a week, while infection from without is prevented by subjecting the external wound to rigid antiseptic treatment.

If the hydrogen gas test, either by rectal insufflation or direct inflation of the stomach, yields a positive result, sufficient and reliable information has been gained to warrant laparotomy, as the surgeon has then satisfied himself that he has to deal with an injury which, if not properly treated, is almost certain to result in the death of the patient.

*Laparotomy for Gunshot Wounds of the Stomach and Intestines.*

I have already insisted that in every perforating gunshot wound of the abdomen, all necessary preparations for laparotomy should be made before the existence of visceral wounds of the stomach or intestines has been demonstrated by the application of the hydrogen gas test, as the latter procedure necessitates the administration of an anæsthetic. The stomach can be inflated without an anæsthetic and the existence or absence of perforations demonstrated before any definite plan of treatment is proposed, but rectal insufflation of hydrogen gas should never be undertaken in the diagnosis of gunshot wounds of the gastro-intestinal canal without complete anæsthesia.

Before I was able to demonstrate the existence of visceral wounds of the stomach and intestines without opening the abdominal cavity, I never succeeded in obtaining the consent of the patient and friends to make a laparotomy in cases of gunshot wounds of the abdomen; but since I have been able to tell the people that the course to be pursued will depend upon the result of the test, I have not met with a single refusal. The hydrogen gas flame at the wound of entrance is an argument more potent than words in convincing laymen of the necessity of active surgical interference. If the public understands that the abdomen will only be opened after the surgeon has satisfied himself and has demonstrated the existence of a mortal injury, the patient and his friends will be only too anxious to avail themselves of the benefits to be derived from the only resource which promises any hope of saving life.

*Medico-Legal Responsibilities in the Performance of  
Laparotomy in the Treatment of Perforating  
Wounds of the Abdomen.*

As in private practice the treatment of penetrating wounds of the abdomen always involves great medico-legal responsibilities, it becomes of the greatest importance to arrive at positive and reliable conclusions in reference to the character of the injury before the patient is subjected to the additional risks to life incident to an abdominal section.

We will suppose a case. In a quarrel a man is shot in the abdomen. The assailant is placed under arrest. The surgeon who is called establishes the fact that the bullet has entered the abdominal cavity, and from the point of entrance and its probable direction he has reason to believe that it has wounded some part of the gastro-intestinal canal, and he concludes to verify his diagnosis by an exploratory laparotomy; the operation is performed, the gastro-intestinal canal is examined in its whole length, but after

the most careful inspection no visceral wound is found. Over an hour is consumed in the examination, during which time the peritoneal cavity is exposed more or less to infection. The wound is closed and the patient dies of shock in two or three hours, or of septic peritonitis on the third or fourth day. The attorney for the State charges the defendant with murder. During the trial the defense will very naturally raise the questions: "Did the man die from the effects of the injury or the operation?" "Shall the defendant be tried for assault and battery or for murder?" During the trial the attending surgeon is made a target for a volley of a medley of scientific and unscientific questions by the cunning attorney for the defense in the attempt to save his client from the gallows or a sentence of imprisonment in the State Prison for life, at the expense of the reputation of the surgeon and the respect and good name of the profession he represents.

This picture is not overdrawn. Such cases have happened and will happen again. It is entirely different if the surgeon can, by means of the hydrogen gas test, ascertain the existence or absence of fatal complications without subjecting the patient to any additional risks to life. If the test yields a positive result, the indications for an operation are clear, and are understood and appreciated by laymen who may serve on the jury.

If a laparotomy, performed in the treatment of a mortal injury, is followed by a fatal termination, the result must be charged to the person who inflicted the injury and not to the surgeon who failed in his attempt to save his patient from certain death. If the operation proves successful, the surgeon has not only saved a life, but he has been at the same time instrumental in diminishing the severity of the sentence of the one who inflicted the injury.

*Preparation of the Patient.*

A patient suffering from a perforating wound of the abdomen should be properly prepared before he is subjected to examination by the hydrogen gas test, and, if this yields a positive result, to laparotomy. If the stomach is filled with food, a salt water emetic should be given for the purpose of evacuating the stomach. The rectum and colon should be emptied by a copious enema of lukewarm water to which may be added a tablespoonful of common salt. These precautions greatly facilitate the application of the hydrogen gas test, and guard against possible sources of error in diagnosis; at the same time they leave the gastro-intestinal canal in a better condition for operative treatment and a speedy repair of the sutured wounds. A hypodermatic injection of one-fourth of a grain of morphia and one one-hundredth of a grain of atropia should be given shortly before the anæsthetic is administered, as these drugs in the doses specified assist the action of the anæsthetic, secure rest for the intestines and sustain the action of the heart. If the patient is much prostrated two ounces of whisky diluted with four ounces of warm water should be given *per rectum*. The external wound and the whole abdomen must be thoroughly disinfected.

*Operating Room.*

The room in which the examination is to be made, and possibly laparotomy performed, should be cleared of all draperies, pictures and unnecessary furniture, and the temperature should not be less than 80° F. It is a good plan to sprinkle the bare floor, walls and ceiling with a strong solution of corrosive sublimate or carbolic acid. An ordinary table covered with blankets and a clean sheet will answer for an operating table. Wash basins, dishes and pitchers are to be sterilized by heat. Plenty of aseptic sponges, clean

towels, and hot sterilized water must be provided. A hypodermic syringe and the necessary stimulants must never be absent. A sufficient quantity of hydrogen gas can be generated in from five to fifteen minutes. The articles necessary for applying the hydrogen gas test are a stomach tube and a four gallon rubber balloon in which the gas is stored, which is connected by four or six feet of rubber tubing with the short rectal tube, for which the vaginal tip of an ordinary Davidson's syringe can be used. Wax tapers are useful in lighting the escaping gas.

### *Incision.*

Great diversity of opinion still prevails in regard to where the incision should be made. In the majority of cases the median incision affords advantages which give it the preference. It should always be selected in cases of gunshot wounds of the stomach, and where the wound of entrance is located near the median line, and where it is known that the bullet has taken an antero-posterior course. A median incision affords most ready access in the treatment of wounds of the small intestine.

The result of the hydrogen gas test will prove of much value in deciding the location of the incision. If, in gunshot wounds of the upper portion of the abdomen, direct inflation of the stomach through an elastic tube reveals the existence of perforation of this organ, the median incision should be selected. If rectal insufflation yields a positive result before the gas has passed the ileo-cæcal valve, the incision should be made over the wounded portion of the colon, which is usually indicated by the course of the bullet. A wound in the transverse colon can be found and dealt with most efficiently through a median incision, while perforation of the cæcum or ascending colon calls for a lateral incision directly over the wounded organ, while a lateral incision on



the left side is indicated if from the direction of the bullet it is evident or probable that the colon below the splenic flexure is the seat of the visceral injury. In the treatment of a gunshot wound of the colon through a lateral incision it is absolutely necessary to make the incision sufficiently long so as not only to facilitate the finding and suturing of the perforation, but also to enable the surgeon to search for and treat additional injuries. By suturing the external wound with several rows of buried sutures there is but little danger of a ventral hernia following.

Laparotomy performed for the arrest of dangerous hæmorrhage should always be done by making a long median incision which will afford the most direct access to the different sources of hæmorrhage. Very often it will be advisable to make the incision in the line of the wound of entrance, more especially in cases where a lateral incision is indicated from the location of the wound, from the course of the bullet, and from the results obtained by application of the hydrogen gas test.

#### *Arrest of Hæmorrhage.*

In perforating wounds of the abdomen profuse hæmorrhage is more frequently of parenchymatous and venous than of arterial origin. Gunshot wounds of the liver, spleen, kidneys and the mesentery give rise to profuse and often fatal hæmorrhage. After opening of the peritoneal cavity it is often very difficult to find the bleeding points, as the blood accumulates as rapidly as it is sponged out, and it becomes necessary to resort to special means in order to arrest the profuse bleeding sufficiently to find the source of hæmorrhage.

One of two resources should be employed: 1. Digital compression of the aorta. 2. Packing the abdominal cavity with a number of large sponges. Digital compression of the aorta below

the diaphragm can be readily made by an assistant introducing his hand through the abdominal incision, which in such a case must be larger than under ordinary circumstances. Compression of the abdominal aorta immediately below the diaphragm will promptly arrest the hæmorrhage from any of the abdominal organs for a sufficient length of time to enable the surgeon to find the source of hæmorrhage and carry out the necessary treatment for its permanent arrest.

Hæmorrhage from a perforated, lacerated kidney may demand a nephrectomy. A similar wound of the liver is cauterized with the actual cautery or tamponned with a long strip of iodoform gauze, one end of which is brought out of the external wound. A wound of the spleen, if the hæmorrhage cannot be arrested by the antiseptic tampon, necessitates splenectomy. Very troublesome hæmorrhage is often met with from wounds of the mesentery.

When multiple perforations of the mesentery and visceral wounds of the stomach or intestines are the source of hæmorrhage, it is a good plan to pack the abdominal cavity with a number of large sponges to each of which a long strip of iodoform gauze is securely tied, these strips being allowed to hang out of the wound in order that none of the sponges may be lost or forgotten in the abdominal cavity after the completion of the operation. The sponges make sufficient pressure to arrest parenchymatous oozing as well as venous hæmorrhage if they are placed at different points against the mesentery and between the intestinal coils. The sponges are removed one by one from below upwards and the bleeding points secured as fast as they are uncovered.

The ligation of mesenteric vessels, both arteries and veins, should be done by applying the ligature *en masse*. Thornton's curved hæmostatic forceps is the most useful instrument for this purpose. Catgut should never be relied upon in

tying a mesenteric vessel, as this material, for several reasons which it is not necessary to mention here, is greatly inferior to fine silk. Troublesome hæmorrhage from a large visceral wound of the stomach and intestines is best controlled by hemming the margin of the wound with fine silk. If hæmorrhage is profuse this must be attended to before anything is done in the way of finding or suturing of the visceral wounds.

*Search for Perforations.*

If the hydrogen gas test has been employed with a positive result before the abdomen was opened, there will be no difficulty experienced in finding the first opening. If the stomach was inflated directly through an elastic tube and the test has shown the presence of a perforation, a median incision is made from the tip of the ensiform cartilage to the umbilicus and the stomach drawn forward into the wound. If no perforation is found in the anterior wall, the insufflation is repeated, and the escaping gas will direct the surgeon to the perforation. After closing the perforation the stomach is again inflated, and if a second perforation exists it is readily detected by this test. The possibility of the existence of a third perforation should be remembered, consequently a third inflation becomes necessary. A second and a possible third perforation can also be detected by inflating the stomach directly through the first and second perforations.

If the wound implicates the abdominal cavity below the stomach, the hydrogen gas test is applied by insufflation *per rectum*. If the test has yielded a positive result, the lowest perforation is readily found by examining the intestine at a point where the distended and empty portions join, as the leakage of gas through the perforation prevents inflation higher up. In one of my experiments I carried the inflation so far that the intra-abdominal pressure caused by an immense

free tympanites not only prevented the inflation of the intestine above the first perforation, but it also forced out the gas from the intestine below the perforation. If, however, the track of the bullet is enlarged down to the peritoneum, as should be done in the diagnosis of all perforating gunshot wounds of the abdomen before the hydrogen gas test is applied, such an occurrence is impossible, as the gas will escape through the external wound as fast as it enters the peritoneal cavity.

If the intestine is found distended below the first discovered perforation, it is an absolute proof that no perforations exist lower down in the intestinal canal, and hence that it is unnecessary to lose any time in looking for perforations in that direction.

As soon as the lowest perforation has been found, rectal insufflation should be suspended. If possible, the perforated portion of the intestine should now be brought forward into the wound, and after emptying the intestine below the perforation as far as possible of its gas, the bowel is compressed below the perforation by an assistant, and the intestine higher up is inflated through the wound. As a matter of course, a perfectly aseptic glass tube should be inserted into the rubber tube instead of the tube used in the rectum. The inflation is now carried as far as the second opening, when the first opening is sutured, and after disinfection the intervening portion of the intestine is replaced in the abdominal cavity. Further inflation is now made through the second opening, and if a third one is found, the second is sutured, and so on until the entire intestinal canal has been thoroughly subjected to the test. By following this plan extensive eventration is rendered superfluous and the overlooking of a perforation is made absolutely impossible. Extensive eventration in the search for perforations, and undiscovered perforations figure largely as

causes of death in gunshot wounds of the abdomen treated by laparotomy, and both of these sources of danger are avoided by a thorough and systematic employment of the hydrogen gas test.

*Suturing of Wounds of the Stomach and Intestines.*

Trimming the margins of the visceral wounds is not only superfluous, but absolutely harmful, as it requires a useless expenditure of time and may become an additional source of hæmorrhage. The same can be said of the Czerny-Lembert suture. All that is required in the treatment of a visceral wound of the stomach and intestines is to turn the margins of the wound inwards and bring into apposition healthy serous surfaces by a few points of interrupted sero-muscular sutures. Fine aseptic silk should be used for the sutures. It is sufficient to use from four to six sutures to an inch. Wounds of the stomach should be sutured in a line parallel with the long axis of the organ. Wounds of the intestine should be closed transversely, with a view of preventing constriction of the lumen. Defects an inch and a half in length on the convex border can be closed safely in this manner without fear of causing intestinal obstruction, while much smaller defects on the mesenteric side often necessitate a resection, not only because the vascular supply in the corresponding portion of the intestine would be inadequate, but also for the reason that a sufficiently sharp flexion might be produced at the seat of suturing to become a source of intestinal obstruction.

*Enterectomy.*

Enterectomy often becomes necessary in cases of double perforation, and in marginal wounds of the mesenteric border. If in cases of multiple perforations it becomes necessary to make a double enterectomy, and the intervening portion of the small intestine is not more than two or three feet in length, it is best to resect it at the same



time, as the immediate effect of the operation will be less severe than a double resection with a corresponding double enterorrhaphy. The mesentery corresponding to the portion of intestine to be removed should be tied in small sections with fine silk before the bowel is excised.

*Restoration of the Continuity of the Intestinal Canal after Enterectomy by Lateral Apposition with Decalcified, Perforated, Moist, Bone Plates.*

Cases of gunshot wounds of the intestines requiring enterectomy are always grave, and anything which can be done to shorten the operation must add to the chances of recovery. Circular enterorrhaphy requires a great deal of time and is less certain in its results than lateral apposition with decalcified bone plates, and for these reasons the latter procedure deserves the preference in uniting the bowel after resection for gunshot wounds of the intestine. For the full technique of this part of the operation I must refer the reader to my article read in the Surgical Section of the American Medical Association at its last meeting, and published in THE JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION, June 14, 1890.

*Omental Grafting.*

If the bowel at the seat of suturing show evidences of contusion, the line of suturing and the damaged portion of the bowel should be covered by an omental graft, which is fastened in its place on the mesenteric side by passing two catgut sutures in the line of the mesenteric vessels through both ends of the graft and the mesentery, and tying them loosely. Before the graft is planted, the surface of the bowel and the surface of the graft which is to be brought in contact with it are scarified with the point of an aseptic needle.

*Irrigation of Abdominal Cavity.*

This is only necessary if fæcal extravasation or escape of stomach contents has occurred, an acci-

dent which, if it has not occurred before the abdomen has been opened, should be carefully avoided during the manipulation of the wounded intestines. Flushing the peritoneal cavity with warm sterilized water not only clears it of infectious material, but acts at the same time as a stimulant to the flagging circulation. After completion of the irrigation the patient is placed on his side, and in this manner the fluid contents of the abdominal cavity are poured out. The cavity is then rapidly dried with large sponges wrung out of a weak antiseptic solution.

#### *Drainage.*

Cases which require irrigation also require drainage. Other indications for drainage are visceral wounds of the liver and wounds of the pancreas, spleen, and kidneys, where extirpation of the wounded part of the organ, or the whole organ is deemed unnecessary, and the existence of parenchymatous hæmorrhage which cannot be remedied by any of the different hæmostatic measures.

#### *Closure of External Incision.*

Incisions through the median line are rapidly closed by one row of silk sutures which include all of the tissues of the margins of the wound. Incisions made in any other place are to be closed by two or three rows of deep catgut sutures, and a superficial row of silk sutures.

#### *After-Treatment.*

Absolute rest must be strictly enforced. Opium must be given in sufficient doses to quiet the peristaltic action of the intestines. No food should be given by the stomach for at least forty-eight hours. During this time brandy and water in small doses frequently repeated are agreeable to the patient, they quench thirst and exert a favorable influence upon the circulation. If more active stimulation is required to overcome

shock and the effects of hæmorrhage, whiskey, ether, musk or camphor can be injected subcutaneously or *per rectum*, while the peripheral circulation is restored by applying dry heat to the extremities and trunk. Should symptoms of peritonitis set in, a brisk saline cathartic should be given at the end of forty-eight hours, as at this time the intestinal wounds will have become sufficiently united to resist the violent peristalsis provoked by the cathartic, while the removal of the intestinal contents and the absorption of septic material from the peritoneal cavity are not only the most efficient means of cutting short a fatal disease, but also of placing the wounds in the most favorable condition for rapid repair.

If the case progresses favorably, liquid food by the stomach can be allowed at the end of the second day and digestible solid food at the end of the first week. Under ordinary circumstances no effort is made to move the bowels until the end of the fourth or fifth day. If early feeding becomes necessary in marantic or exsanguinated patients, this can be done by rectal alimentation. Patients should not be allowed to leave the bed until the external wound has firmly united throughout, as any imprudence in this direction is liable to be punished by the formation of a ventral hernia. The sutures are removed on the eighth day and the patient is directed to wear an abdominal supporter for several weeks after he has left his bed.

#### SUGGESTIONS FOR THE CONSIDERATION OF MILITARY AUTHORITIES AND MILITARY SURGEONS.

The object of battle is to kill and disable the combatants until the question of victory is decided in favor of the army which exceeds in numbers, or is superior in courage or more skilled in warfare. Very little has been done so far in the way of aggressive surgical interference for heroes who fell mortally wounded in the line of

battle in the defense of their country, their ruler, their families, their homes and their rights. The time has come when in case of war adequate provisions should be made on the field of battle near the rear line for the prompt treatment of perforating gunshot wounds of the abdomen. It is difficult to conceive how many valuable lives have been sacrificed on the field of battle during the innumerable wars recorded in the history of the world which now are within the reach of successful surgical interference. Thousands of lives have been lost from internal hæmorrhage alone which could now be saved by an early laparotomy.

In future wars it is the duty of every civilized nation to do all that modern surgery can do in the treatment of perforating gunshot wounds of the abdomen on the battle field. Every soldier who has been in active military service can recall instances where comrades dropped in the ranks with a mortal bullet wound of the abdomen, who lived for several hours and died from hæmorrhage, often forgotten and uncared for in the excitement of the conflict. Justice, patriotism, humanity and the present status of abdominal surgery demand that in future wars enough men shall be detailed from each company to convey the severely wounded to the rear of the line of battle, where they can receive prompt and efficient surgical aid, and where, if die they must, the last hour of their life shall be peaceful, surrounded by those who will add to their comfort and administer words of consolation as the immortal spirit leaves the maimed body for the future world.

For the purpose of carrying into effect the modern aggressive treatment of perforating gunshot wounds of the abdomen in military practice, it will be necessary to erect a large tent for every brigade, in a safe place, but sufficiently near the line of battle to be within easy reach. This tent

should be heated with gas stoves and provided with all the necessary instruments, dressing material and medicines required in the operative treatment of gunshot wounds of the abdominal viscera. One surgeon specially qualified for his work should be detailed to superintend the surgical work, assisted by a sufficient number of reliable assistants. This tent should be used exclusively for the treatment of perforating wounds of the abdomen.

If, as is so often the case in gunshot wounds of the abdomen made with bullets of large calibre, life is threatened by hæmorrhage, the abdomen, after rapid but thorough disinfection, should be opened at once, and after the bleeding has been arrested, visceral injuries of the gastro-intestinal canal should be sought for by applying the hydrogen gas test in the manner described above. The use of this test will not only shorten the time required in the completion of the operation, but it will also guard against two grave sources of danger—extensive eventration and leaving undiscovered and unsutured perforations. Enterectomy will be more frequently made necessary in military than private practice on account of the large size of projectiles used in warfare as compared with those used in private life. Restoration of the continuity of the intestinal canal after enterectomy for gunshot wounds of the abdomen should be done by a method which saves valuable time and secures the best results—advantages which are gained by the use of decalcified, perforated bone plates. Patients who rally from the operation should subsequently either receive the necessary after treatment in hospital tents, or should be later transported with the greatest care to the nearest hospital.

*The Correct Diagnosis and Proper Treatment of Gunshot Wounds of the Stomach and Intestines Require a Degree of Skill and Dexterity which can only be Acquired by Experiments on the Lower*



*Animals.* Even the minutest descriptions of the details to be observed and applied in the diagnosis and treatment of gunshot wounds of the abdomen are utterly inadequate to prepare a surgeon to interpret correctly the symptoms and signs presented by penetrating gunshot wounds of the abdomen, or to meet the often unexpected emergencies in their treatment. Operative courses on the cadaver are valuable and useful, but they never can take the place of experiments on the living animal. This is more especially true in reference to the use of the hydrogen gas test as a diagnostic measure, and the manual dexterity required in the surgical treatment of internal hæmorrhage and visceral wounds. A certain amount of experimental experience is absolutely required in the preparation of the surgeon for the kind of abdominal work which requires not only courage, good judgment, and a thorough knowledge of every step in diagnosis and treatment, but also a manual dexterity which cannot be acquired in any other way.

#### CONCLUSIONS.

1. In gunshot wounds of the abdomen, in the absence of external fæcal extravasation and prolapse of the omentum, it is absolutely necessary to establish the fact that penetration has or has not taken place by enlarging the wound down to the peritoneum, if the bullet has entered the peritoneal cavity, or in non-penetrating wounds, sufficiently far to show conclusively that the peritoneal cavity has not been invaded.

2. In a fair percentage of cases a bullet which penetrates the abdominal cavity does not produce visceral injuries which require treatment by laparotomy, and such cases, as a rule, recover without surgical interference.

3. Absence of visceral lesions which require treatment by laparotomy is most frequently met with in perforating gunshot wounds of the ab-

domen, if the wound of entrance is at or above the level of the umbilicus, and if its course is in an antero-posterior direction.

4. In transverse and oblique gunshot wounds of the abdomen at a point below the level of the umbilicus, multiple perforations of the intestines may be confidently expected.

5. The general and local symptoms, with the exception of external fæcal extravasation, are of absolutely no value in the differential diagnosis between simple penetrating gunshot wounds of the abdomen and penetrating gunshot wounds of the abdomen complicated by serious visceral injuries which demand prompt surgical interference.

6. Alarming internal hæmorrhage caused by perforating gunshot wounds of the abdomen can be recognized by the symptoms which characterize progressive acute anæmia, and by the physical signs due to the presence of fluid in the free peritoneal cavity.

7. Dangerous internal hæmorrhage furnishes a positive and urgent indication for treatment by laparotomy. The incision in such cases should be ample and through the median line.

8. After opening the peritoneal cavity for the treatment of alarming hæmorrhage, temporary hæmostasis should be secured by digital compression of the aorta below the diaphragm, or by packing the abdominal cavity with a requisite number of large sponges until the bleeding points can be discovered and the hæmorrhage arrested by permanent measures.

9. The existence of wounds of the stomach and intestine large enough to permit the escape of the contents of these organs can be infallibly demonstrated by the application of the hydrogen gas test before the abdomen is opened.

10. Direct insufflation of the stomach through an elastic tube is preferable to rectal insufflation as a diagnostic test in all cases where, from the location of the wound of entrance and the proba-

ble course of the bullet, there is reason to believe that this organ is the seat of injury.

11. The existence and probable location of gunshot wounds of the intestines can be ascertained by rectal insufflation of hydrogen gas.

12. Through insufflation without evidences of free tympanites or escape of gas through the external wound demonstrates either the absence of perforations, or that if present they are too small for leakage to take place; consequently the result of the test is a strong argument in favor of non-interference.

13. The hydrogen gas test should invariably be relied upon in searching for the perforations after the abdominal cavity has been opened, as this method of examination, if properly and carefully conducted, makes extensive eventration unnecessary, and never fails in revealing every perforation.

14. After opening the abdominal cavity for the treatment of gunshot wounds of the intestines, the lowest perforation is pointed out by rectal insufflation of hydrogen gas, but in the search for additional perforations the inflation should be made directly through the perforation last sutured, while the portion of the intestines which has been tested and the perforation sutured is replaced in the abdominal cavity.

15. The external wound should never be closed until the whole length of the gastrointestinal canal has been subjected to the hydrogen gas test, in order to guard against the possibility of leaving a perforation undiscovered.

16. The hydrogen gas test under ordinary circumstances does not cause fæcal extravasation, and consequently does not increase the subsequent risks from peritonitis.

17. Pure hydrogen gas is most suitable for insufflation of the gastro-intestinal canal for diagnostic purposes, as this substance is non-irritating, non-toxic, and possesses valuable inhibitory

antiseptic properties, while its exceedingly low specific gravity adds still more to its value when used for this purpose.

18. By following the indications furnished by the hydrogen gas test the surgeon relieves himself of all medico-legal responsibilities in the operative treatment of penetrating gunshot wounds of the abdomen.

19. A gunshot wound of the gastro-intestinal canal sufficiently large to permit escape of the contents of the stomach or intestines must, for all practical purposes, be regarded as a mortal injury, and on this account its treatment by laparotomy is urgently indicated.

20. Laparotomy in the treatment of gunshot wounds of the stomach and intestines should be performed as soon as possible after the infliction of the injury, and always before a septic peritonitis has had time to develop.

21. The closure of bullet wounds of the stomach and intestines is accomplished most speedily, and with a sufficient degree of safety by the application of one row of interrupted sero-muscular sutures of fine aseptic silk.

22. If enterectomy becomes an unavoidable necessity in the treatment of gunshot wounds of the intestines, the continuity of the intestinal canal should be restored by making an anastomosis between the closed ends by lateral apposition with decalcified, perforated, moist, bone plates, as this procedure requires less time and accomplishes the desired result with a greater degree of safety than circular enterorrhaphy.

23. Flushing of the abdominal cavity is to be reserved for cases in which the peritoneal cavity has become contaminated by escape of the contents of the stomach or intestines.

24. Drainage becomes necessary in cases in which the peritoneal cavity has become infected, also in injuries of the liver, and in wounds of the spleen, kidney or pancreas not treated by par-

tial or complete extirpation of the injured organ.

25. The adoption of adequate provisions for the prompt, aggressive treatment of perforating gunshot wounds of the abdomen in hospital tents in the rear of the line of battle, should receive the most serious consideration of military authorities, and military surgeons who will have charge of the wounded in the wars of the future.

26. The necessary diagnostic skill, and requisite manual dexterity in the operative treatment of gunshot wounds of the stomach and intestines, can be acquired only by experiments on the lower animals.







